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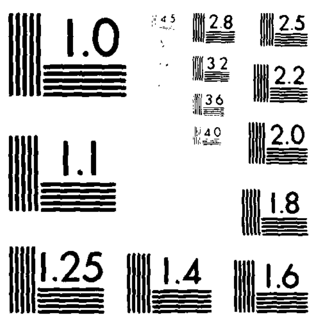

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PROJECT SQUID

FINAL TECHNICAL REPORT

REPORT NO. PU-R2-80

Contract Nos.
N00014-67-0226, N00014-67-A-0226
and
N00014-75-C-1143

FEBRUARY 1980

Project SQUID is a cooperative program of basic research relating to Jet Propulsion. It is sponsored by the Office of Naval Research and is assisted by Purdue University through Contract N00014-75-C-1143, NR-098-038.

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10 K. F. Hoglund

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Molecular Processes	Turbomachinery	Measurement Techniques	
Rate Processes			

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Final Technical Report provides a summary report of the activities under Project SQUID carried out under Contracts N00014-67-0226, N00014-67-A-0226 and N00014-75-C-1143 during the Period Oct. 1967-Dec. 1979 with the Office of Naval Research. Research projects carried out under sub-contract to Purdue University as well as Workshops and Colloquia organized under the auspices of Project SQUID are discussed.

Project SQUID is a continuing program devoted to fundamental research of long range relevance to the technology of jet propulsion.

PROJECT SQUID

FINAL TECHNICAL REPORT

Report No. PU-R2-80

Contract Nos.

N00014-67-0226

N00014-67-A-0226

and

N00014-75-C-1143

February, 1980

School of Mechanical Engineering

Purdue University

West Lafayette, Indiana 47907

ABSTRACT

The Final Technical Report provides a summary report of the activities under Project SQUID carried out under Contracts N00014-67-0226, N00014-67-A-0226 and N00014-75-C-1143. Research projects carried out under sub-contract to Purdue University as well as Workshops and Colloquia organized under the auspices of Project SQUID are discussed.

ACKNOWLEDGEMENT

Project SQUID, administered by the Power Program of the Office of Naval Research, has been devoted to fundamental research of long range relevance in propulsion. It has been assisted, from October 1967 till December 1979, under Contracts Nos. N00014-67-0226, N00014-67-A-0226 and N00014-75-C-1143, by the School of Mechanical Engineering at Purdue University, where jet propulsion has been a thrust area in research and teaching for over forty years.

Thirty university institutions and fourteen industrial research centers have participated in Project SQUID in the period 1967-1979. They were selected each year based entirely on the excellence of their proposals in relation to long-term Navy needs. Their research, which is their primary excitement, has contributed not only great advances but also trained nearly 100 researchers in the field.

Purdue University has been assisted, over the years, by about fifteen external consultants, selected by the ONR, in reviewing on-going and proposed work under Project SQUID. Their service to the research community and the ONR are well-recognized.

Mr. James R. Patton of the Power Program has been the ONR director of SQUID over the entire period, 1967-1979. His sympathy for fundamental research, especially in university institutions, his guidance in the organization of SQUID Workshops and Colloquia and his continuous attempts at relating SQUID research programs to advance development in industry have been greatly appreciated by the research community and the consultants.

Dr. Ralph Roberts and Mr. John Satkowski have been directors of the Power Program during 1967-1975 and 1975-1979 respectively. Their support of a project-type operation in propulsion research with emphasis on three or four selected subject areas at any one time has made Project SQUID as effective as is evident in this Report.

Purdue University is very pleased with its participation in Project SQUID, and looks upon such collaborative efforts with government agencies as a continuing activity of the University in public service.

West Lafayette
February 28, 1980

S.N.B. Murthy

CONTENTS

1. INTRODUCTION

The Office of Naval Research Power Program was assisted by Purdue University under two Contracts as follows.

i) Contract No. N00014-67-A-0226 beginning October 1, 1967 and ending September 30, 1975; and

ii) Contract No. N00014-75-C-1143 beginning October 1, 1975 and ending December 31, 1979.

The Principal Investigators at Purdue University during the period Oct. 1, 1967 through Dec. 31, 1979 were the following.

i) Dr. R.F. Hoglund;

ii) Dr. R. Goulard; and

iii) Dr. S. N. B. Murthy.

The Principal Investigators were assisted by a secretary.

The activities under Project SQUID at Purdue University consisted of the following. Each of the activities was carried out under specific direction and approval of the ONR Power Program.

i) Issuing Call for Proposals, receiving proposals, reviewing proposals along with consultants at an Annual Review Meeting, and submitting a Review Report upon the Proposals to the ONR Power Program.

ii) Assisting the ONR Power Program in the review of on-going research.

iii) Awarding Sub-Contracts for research and administering them as directed and approved by the ONR Power Program; and

iv) Organizing Workshops and Colloquia.

Three types of Reports have been submitted to the ONR Power Program in connection with work accomplished under Project SQUID. They

are the following.

i) Semi-Annual Progress Reports which described the work accomplished under various research projects that were on-going in the period covered by the Report;

ii) Annual Status Reports which provided the status of each project that was on-going in the period covered by the Report; and

iii) Reports on Workshops and Colloquia organized under the Project and issued as and when completed.

It has been the policy of the ONR Power Program to make all reports published under Project SQUID available to public, except the Status Reports which were prepared for official use only.

Proposals submitted to Project SQUID and on-going research contracts under Project SQUID have been reviewed at Annual Review Meetings. Annual Review Meetings have been held as follows.

1) October, 1979: California Institute of Technology, Pasadena, Calif.
2) October, 1978: Yale University, Hartford, Connecticut.
3) March, 1977: Scripps Institution of Oceanography, University of California - San Diego, La Jolla, California.
4) March, 1976: Naval Research Laboratory, Washington, D.C.
5) March, 1975: Southern Methodist University, Dallas, Texas.
6) March, 1974: The University of Michigan, Ann Arbor, Michigan.
7) March, 1973: Virginia Polytechnic Institute and State University, Blacksburg, Virginia.
8) March, 1972: University of California - San Diego, La Jolla, California.
9) March, 1971: Yale University, Hartford, Connecticut.
10) March, 1970: Massachusetts Institute of Technology, Boston, Massachusetts.
11) March, 1969: University of Denver, Denver, Colorado.
12) February, 1968: U.S. Naval Weapons Center, China Lake, California.
13) March, 1967: Purdue University, West Lafayette, Indiana.

1.1. Outline of Report

Section 2 provides a listing of the Sub-Contracts for Research awarded during the years 1967-79. Following the listing, each Sub-Contract is described along with the name of the Principal Investigator, objective of research, its significance, the project period, the SQUID Reports published and other publications.

A list of Technical Reports published under each Sub-Contract and the overall list of "other publications" during 1967-79 are provided in Section 3.

Reviews, Workshops and Colloquia conducted under Project SQUID during 1967-79 are described in Section 4.

Other Special Services provided under Project SQUID are described in Section 5.

Finally, Section 6 provides a short discussion of objectives, procedure, achievements and some possible future directions. It is proposed to elaborate on this Section with the ONR Power Program as and when need arises.

2. SUB-CONTRACTS FOR RESEARCH

The Sub-Contracts for Research awarded by Purdue University, upon specific approval by the ONR Power Program, are listed as follows along with the Semi-Annual and Status Reports that covered the research accomplished in that period.

Section 2.1	3.1.1978	through	12.31.1979
Section 2.2	10.1.1977	through	2.28.1978
Section 2.3	10.1.1976	through	9.30.1977
Section 2.4	10.1.1975	through	9.30.1976
Section 2.5	10.1.1974	through	9.30.1975
Section 2.6	10.1.1973	through	9.30.1974
Section 2.7	10.1.1972	through	9.30.1973
Section 2.8	10.1.1971	through	9.30.1972
Section 2.9	10.1.1970	through	9.30.1971
Section 2.10	10.1.1969	through	9.30.1970
Section 2.11	10.1.1968	through	9.30.1969
Section 2.12	10.1.1967	through	9.30.1968

In a particular period as above, it will be observed that occasionally a Sub-Contractor has changed the title of his research project. In such cases, both titles are provided, and the investigator's name is marked with an asterisk.

2.1 March 1, 1978 through December 31, 1979

It will be observed that this period covers the following.

i) 3.1.1978 to 2.28.1979; and

ii) 3.1.1979 to 12.31.1979.

No new Sub-Contracts were awarded in the period 3.1.1979 to 12.31.1979. Sub-Contracts in operation in the period 3.1.1978 to 2.28.1979 were given extensions where necessary.

2.1.1 Reference Reports

1. Semi-Annual Report dated 4.1.1978.
2. Semi-Annual Report dated 10.1.1978.
3. Status Report dated November 1978.
4. Semi-Annual Report dated 4.1.1979.

Reference should be made to Section 3.1 for Final Reports received on each of the Projects completed as of 12.31.1979.

2.1.2 Projects

No.	a) Institution b) Title	Principal Investigator
	AERODYNAMICS AND TURBOMACHINERY	
1.	a. The University of Michigan b. Three Dimensional Transonic Flows in Compressors and Channels	T.C. Adamson, Jr., M. Sichel
2.	a. The Pennsylvania State University b. Axial Flow Fan Stage Unsteady Performance	E. P. Bruce
3.	a. United Technologies Research Center b. Investigation of the Effects of High Aerodynamic Loading on a Cascade of Oscillation Airfoils	F.O. Carta, A.O. St. Hilaire

No.	a) Institution b) Title	Principal Investigator
4.	a) The University of Washington b) Investigation of Adverse Pressure Gradient Corner Flows	F.B. Gessner,
5.	a) Stanford University b) Transitory Stall in Diffusers	J.P. Johnston, S.J. Kline,
6.	a) Virginia Polytechnic Institute and State University b) An Investigation of Pressure Fluctuations and Stalling Characteristics on Rotating Axial-Flow Compressor Blades	W.F. O'Brien, Jr., H.L. Moses
7.	a) Colorado State University b) Effects of Turbulence on Flow Through an Axial Compressor Blade Cascade	Willy Z. Sadeh
8.	a) Southern Methodist University b) Fundamental Research on Adverse Pressure Gradient Induced Turbulent Boundary Layer Separation	Roger L. Simpson
	COMBUSTION AND CHEMICAL KINETICS	
1.	a) AeroChem Research Laboratories, Inc. b) Preparation of Manuscript on Ionization in Flames	Hartwell F. Calcote
2.	a) University of Missouri - Columbia b) A Shock Tube Study of H_2 and CH_4 Oxidation with N_2O as Oxidant	Anthony M. Dean
3.	a) AeroChem Research Laboratories b) High Temperature Fast-Flow Reactor Chemical Kinetics Studies	Arthur Fontijn
4.	a) Kansas State University b) Isotopic Studies of the Chemical Mechanisms of Soot Nucleation	T.W. Lester, J.F. Merklin

No.	a) Institution b) Title	Principal Investigator
5.	a) Cornell University b) Pyrolysis of Synthetic Fuels Using the Laser-Powered Homogeneous	W.J. McLean
6.	a) Princeton University b) Fundamental Studies on Turbulent, Swirling Jet Ignition	W.A. Sirignano
7.	a) Yale University b) Combustion Kinetics and Reactive Scattering Experiments	J.B. Fenn
8.	a) Massachusetts Institute of Technology b) Experimental and Theoretical Studies of Molecular Collisions and Chemical Instabilities	John Ross
	MEASUREMENTS	
1.	a) Yale University b) Turbulent Structure Determination by Ramanography	R.K. Chang, B.T. Chu
2.	a) United Technologies Research Center b) CARS Investigation in Sooting and Turbulent Flames	Alan C. Eckbreth
3.	a) General Electric Company b) Laser Raman Probe for Combustion Diagnostics	M. Lapp
4.	a) Polytechnic Institute of New York b) An Experimental Study of Reactive and Non-reactive Flows in a Jet and Channel	S. Lederman*
5.	a) Polytechnic Institute of New York b) Turbulence Measurements in Jets Flames and Combustors	S. Lederman*

No.	a) Institution b) Title	Principal Investigator
	TURBULENCE	
1.	a) University of Southern California b) Large-Scale Structure Interactions in a Two-Dimensional Turbulent Mixing-Layer	F.K. Browand
2.	a) The University of Sheffield b) The Structure of Eddies in Turbulent Flames	N.A. Chigier
3.	a) University of California - San Diego b) Heterogeneous Turbulent Flows Related to Propulsive Devices	Paul A. Libby
4.	a) California Institute of Technology b) Research on Turbulent Mixing	A. Roshko
5.	a) The University of Colorado b) Swirling Heated Turbulent Flows as Related to Combustion Chambers	M.S. Uberoi
6.	a) Aeronautical Research Associates of Princeton, Inc. b) Second-Order Closure Modeling of Turbulent Combustion	Ashok K. Varma
7.	a) University of Southern California b) Large Scale Structure and Entrainemnt in the Turbulent Mixing Layer	F.K. Browand
8.	a) Michigan State University b) Binary Gas Mixing with Large Density Difference in Homogeneous Turbulence	J.F. Foss

2.2 October 1, 1977 through February 28, 1978

It will be observed that this period covers a period of five (5) months.

The ONR Power Program decided in 1977 to change the Project SQUID year from October 1 a year to September 30 of the following year. Accordingly the period 10.1.1977 to 2.28.1978 was treated as a distinct period in itself.

2.2.1 Reference Reports

Semi-Annual Report dated October 1, 1977.

2.2.2 Projects

No.	a) Institution b) Title	Principal Investigator
	AERODYNAMICS AND TURBOMACHINERY	
1.	a) The University of Michigan Three Dimensional Transonic Flows in Compressors and Channels	T.C. Adamson, Jr., M. Sichel
2.	a) The Pennsylvania State University b) Axial Flow Fan Stage Unsteady Performance	Edgar P. Bruce
3.	a) United Technologies Research Center b) Investigation of the Effects of High Aerodynamic Loading on a Cascade of Oscillating Airfoils	Franklin O. Carta, Arthur O. St. Hilaire
4.	a) The University of Washington b) Investigation of Adverse Pressure Gradient Corner Flows	F.B. Gessner

No.	a) Institution b)	Principal Investigator
5.	a) Stanford University b) Transitory Stall in Diffusers	James P. Johnston, Stephen J. Kline
6.	a) Virginia Polytechnic Institute and State University b) An Investigation of Pressure Fluctuations and Stalling Characteristics on Rotating Axial-Flow Compressor Blades	H.L. Moses, W.F. O'Brien
7.	a) Colorado State University b) Effects of Turbulence on Flow Through an Axial Compressor Blade Cascade	Willy Z. Sadeh
8.	a) Southern Methodist University b) Fundamental Research on Adverse Pressure Gradient Induced Turbulent Boundary Layer Separation	Roger L. Simpson
	COMBUSTION AND CHEMICAL KINETICS	
1.	a) University of Missouri - Columbia b) A Shock Tube Study of H_2 and CH_4 Oxidation with N_2O as Oxidant	Anthony M. Dean
2.	a) Yale University b) Combustion Kinetics and Reactive Scattering Experiments	J.B. Fenn
3.	a) AeroChem Research Laboratories b) High Temperature Fast-Flow Reactor Chemical Kinetics Studies	Arthur Fontijn
4.	a) Massachusetts Institute of Technology b) Experimental and Theoretical Studies of Molecular Collisions and Chemical Instabilities	John Ross

No.	a) Institution b) Title	Principal Investigator
	MEASUREMENTS	
1.	a) Polytechnic Institute of New York b) Turbulence Measurements in Jets Flames and Combustors	S. Lederman
2.	a) General Electric Company b) Laser Raman Probe for Combustion Diagnostics	Marshall Lapp
3.	a) Stanford University b) Investigation of Novel Laser Anemometer and Particle-Sizing Instrument	S.A. Self
	TURBULENCE	
1.	a) University of Southern California b) Large Scale Structure and Entrainment in the Turbulent Mixing Layer	F.K. Browand
2.	a) Michigan State University b) Binary Gas Mixing with Large Density Difference in Homogeneous Turbulence	J.F. Foss
3.	a) University of California - San Diego b) Heterogeneous Turbulent Flows Related to Propulsive Devices	Paul A. Libby
4.	a) California Institute of Technology b) Research on Turbulent Mixing	A. Roshko
5.	a) The University of Colorado b) Swirling Heated Turbulent Flows as Related to Combustion	Mahinder S. Uberoi
6.	a) Aeronautical Research Associates of Princeton, Inc. b) Second-Order Closure Modeling of Turbulent Combustion	Ashok K. Varma

2.3 October 1, 1976 through September 30, 1977

2.3.1 Reference Reports

1. Semi Annual Report dated October 1, 1976.
2. Semi-Annual Report dated April 1, 1977.
3. Status Report dated November, 1976.

2.3.2 Projects

No.	a) Institution b) Title	Principal Investigator
	AERODYNAMICS AND TURBOMACHINERY	
1.	a) The University of Michigan b) Three Dimensional Transonic Flows in Compressors and Channels	T.C. Adamson, M. Sichel
2.	a) The Pennsylvania State University b) Axial Flow Fan Stage Unsteady Performance	Edgar P. Bruce*
3.	a) The Pennsylvania State University b) The Unsteady Response of an Axial Flow Rotor to Distorted Inflows	Edgar P. Bruce*
4.	a) United Technologies Research Center b) Investigation of the Effects of High Aerodynamic Loading on a Cascade of Oscillating Airfoils	Franklin O. Carta, Arthur O. St. Hilaire
5.	a) The University of Washington b) Investigation of Adverse Pressure Gradient Corner Flows	F.B. Gessner
6.	a) Stanford University b) Transitory Stall in Diffusers	James P. Johnston, Stephen J. Kline
7.	a) Virginia Polytechnic Institute and State University	H.L. Moses, W.F. O'Brien, Jr.

No.	a) Institution b) Title	Principal Investigator
7.	b) An Investigation of pressure Fluctuations and Stalling Characteristics on Rotating Axial-Flow Compressor Blades	
8.	a) Colorado State University b) Effects of Turbulence on Flow Through an Axial Compressor Blade Cascade	Willy C. Sadeh
9.	a) Southern Methodist University b) Fundamental Research on Relaminarization Phenomena as Produced in Nozzles and Turbines	Roger L. Simpson
	COMBUSTION AND CHEMICAL KINETICS	
1.	a) University of Missouri - Columbia b) A Shock Tube Study of H_2 and CH_4 Oxidation with N_2O as Oxidant	Anthony M. Dean
2.	a) Yale University b) Kinetics of Phase Change and Energy Exchange	J.B. Fenn
3.	a) AeroChem Research Laboratories b) High Temperature Fast-Flow Reactor Chemical Kinetics Studies	Arthur Fontijn
4.	a) Massachusetts Institute of Technology b) Experimental and Theoretical Studies of Molecular Collisions and Chemical Instabilities	John Ross
5.	a) Case Western Reserve University b) A Basic Study on the Mechanism of Inflammability Limits and the Behavior of Near-Limit Flames	James, S. T'ien
	MEASUREMENTS	
1.	a) United Technologies Research Center b) Investigation to Extend the Applicability of Laser Raman Scattering Diagnostic Techniques to Practical Combustion Systems	Alan C. Eckbreth

No.	a) Institution b) Title	Principal Investigator
2.	a) Polytechnic Institute of New York b) Temperature, Concentration and Velocity Measurements in a Jet and Flame	S. Lederman
3.	a) General Electric Company b) Laser Raman Probe for Combustion Diagnostics	Marshall Lapp
4.	a) Stanford University b) Investigation of Novel Laser Anemometer and Particle-Sizing Instrument	S.A. Self
	TURBULENCE	
1.	a) TRW Systems, Inc. b) The Coherent Flame Model for Turbulent Chemical Reactions	James E. Broadwell
2.	a) University of Southern California b) Large Scale Structure and Entrainment in the Turbulent Mixing Layer	F.K. Browand
3.	a) Michigan State University b) Binary Gas Mixing with Large Density Difference in Homogeneous Turbulence	J.F. Foss
4.	a) University of California - San Diego b) Heterogeneous Turbulent Flows Related to Propulsive Devices	Paul A. Libby
5.	a) California Institute of Technology b) Research on Turbulent Mixing	A. Roshko
6.	a) The University of Colorado b) Swirling Heated Turbulent Flows as Related to Combustion Chambers	Mahinder S. Uberoi
7.	a) Aeronautical Research Associates of Princeton, Inc. b) Second-Order Closure Modeling of Turbulent Combustion	Ashok K. Varma

2.4 October 1, 1975 through September 30, 1976

2.4.1 Reference Reports

1. Semi-Annual Report dated October 1, 1975.
2. Semi-Annual Report dated April 1, 1976.
3. Status Report dated November, 1975.

2.4.2 Projects

No.	a) Institution b) Title	Principal Investigator
	AERODYNAMICS AND TURBOMACHINERY	
1.	a) The University of Michigan b) Unsteady Transonic Flows in Two Dimensional Channels	T.C. Adamson, Jr., M. Sichel *
2.	a) The University of Michigan b) Three Dimensional Transonic Flows in Compressors and Channels	T.C. Adamson, Jr., M. Sichel *
3.	a) The Pennsylvania State University b) Measurement and Analysis of the Unsteady Normal Force and Pitching Moment of an Axial Flow Fan Rotor Blade Element	E.P. Bruce *
4.	a) The Pennsylvania State University b) The Unsteady Response of an Axial Flow Rotor to Distorted Inflows	E.P. Bruce *
5.	a) United Technologies Research Center b) Investigation of Dynamic Stall on a Cascade of Oscillating Airfoils	Franklin O. Carta *
6.	a) United Technologies Research Center b) Investigation of the Effects of High Aerodynamic Loading on a Cascade of Oscillating Airfoils	Franklin O. Carta *

No.	a) Institution b) Title	Principal Investigator
7.	a) Virginia Polytechnic Institute and State University b) An Investigation of Pressure Fluctuations and Stalling Characteristics on Rotating Axial-Flow Compressor Blades	W.F. O'Brien, H.L. Moses
8.	a) Bell Aerospace Company b) Nontangential Injection of Single and Two-Phase Jets into Subsonic Flow	G. Rudinger
9.	a) Colorado State University b) Effects of Turbulence on Flow Through an Axial Compressor Blade Cascade	Willy C. Sadeh
10.	a) Southern Methodist University b) Fundamental Research on Relaminarization Phenomena as Produced in Nozzles and Turbines	Roger L. Simpson
	<u>COMBUSTION AND CHEMICAL KINETICS</u>	
1.	a) University of Missouri - Columbia b) A Shock Tube Study of H_2 and CH_4 Oxidation with N_2O as Oxidant	Anthony M. Dean
2.	a) Yale University b) Kinetics of Phase Change and Energy Exchange	J.B. Fenn
3.	a) AeroChem Research Laboratories b) High Temperature Fast-Flow Reactor Chemical Kinetics Studies	Arthur Fontijn
4.	a) Massachusetts Institute of Technology b) Experimental and Theoretical Studies of Molecular Collisions and Chemical Instabilities	John Ross
5.	a) Case Western Reserve University b) A Basic Study on the Mechanism of Inflammability Limits and the Behavior of Near-Limit Flames	James S. T'ien

No.	a) Institution b) Title	Principal Investigator
	MEASUREMENTS	
1.	a) United Technologies Research Center b) Investigation to Extend the Applicability of Laser Raman Scattering Diagnostic Techniques to Practical Combustion Systems	Alan C. Eckbreth
2.	a) Polytechnic Institute of New York b) Temperature, Concentration and Velocity Measurements in a Jet and Flame	S. Lederman
3.	a) General Electric Company b) Laser Raman Probe for Combustion Diagnostics	Marshall Lapp
4.	a) Stanford University b) Investigation of Novel Laser Anemometer and Particle-Sizing Instrument	S.A. Self
	TURBULENCE	
1.	a) TRW Systems, Inc. b) The Coherent Flame Model for Turbulent Chemical Reactions	J.E. Broadwell
2.	a) University of Southern California b) Large Scale Structure and Entrainment in the Turbulent Mixing Layer	Frederick K. Browand
3.	a) Michigan State University b) Binary Gas Mixing with Large Density Difference in Homogeneous Turbulence	J.F. Foss *
4.	a) Michigan State University b) Large Density Difference Binary Gas Mixing in Homogeneous Turbulence	J.F. Foss *
5.	a) University of California - San Diego b) Heterogeneous Turbulent Flows Related to Propulsive Devices	Paul A. Libby
6.	a) California Institute of Technology	A. Roshko

No.	a) Institution b) Title	Principal Investigator
	b) Research on Turbulent Mixing	
7.	a) University of Colorado b) Swirling Heated Turbulent Flows as Related to Combustion Chambers	Mahinder S. Uberoi

2.5 October 1, 1974 through September 30, 1975

2.5.1 Reference Reports

1. Semi-Annual Report dated October 1, 1974.
2. Semi-Annual Report dated April 1, 1975.
3. Status Report dated November, 1974.

2.5.2 Projects

No.	a) Institution b) Title	Principal Investigator
	AERODYNAMICS AND TURBO MACHINERY	
1.	a) The University of Michigan b) Unsteady Transonic Flows in Two Dimensional Channels	T.C. Adamson, M. Sichel
2.	a) The Pennsylvania State University b) Measurement and Analysis of the Unsteady Normal Force and Pitching Moment on an Axial Flow Fan Rotor Blade Element	Edgar P. Bruce *
3.	a) The Pennsylvania State University b) Direct Measurement of the Unsteady Normal Force and Pitching Moment on an Axial Flow Fan Rotor Blade Element	Edgar P. Bruce *
4.	a) United Aircraft Research Laboratories b) Investigation of Dynamic Stall on a Cascade of Oscillating Airfoils	Franklin O. Carta
5.	a) Virginia Polytechnic Institute b) An Investigation of Pressure Fluctuations and Stalling Characteristics on Rotating Axial-Flow Compressor Blades	W.F. O'Brien, H.L. Moses
6.	a) Southern Methodist University b) Fundamental Research on Relaminarization Phenomena as Produced in Nozzles and Turbines	Roger L. Simpson

No.	a) Institution b) Title	Principal Investigator
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1.	a) Yale University b) Kinetics of Phase Change and Energy Exchange	J.B. Fenn
2.	a) AeroChem Research Laboratories, Inc. b) High-Temperature Fast-Flow Reactor Chemical Kinetics Studies	Arthur Fontijn
3.	a) Massachusetts Institute of Technology b) Experimental and Theoretical Studies of Molecular Collisions and Chemical Instabilities	John Ross
4.	a) Case Western Reserve University b) A Basic Study on the Mechanism of Inflammability Limits and the Behavior of Near-Limit Flames	James S. T'ien
5.	a) Massachusetts Institute of Technology b) Complex Nucleation Mechanism in Flames	J.B. Howard
	MEASUREMENTS	
1.	a) Polytechnic Institute of New York b) Temperature, Concentration and Velocity Measurements in a Jet and Flame	S. Lederman *
2.	a) Polytechnic Institute of New York b) Concentration and Temperature Measurements in Jets	S. Lederman *
3.	a) General Electric Co. b) Laser Raman Probe for Combustion Diagnostics	Marshall Lapp

No.	a) b)	Principal Investigator
	TURBULENCE	
1.	a) University of Southern California b) Large Scale Structure and Entrainment in the Turbulent Mixing Layer	Frederick K. Browand
2.	a) Michigan State University b) Large Density Difference Binary Gas Mixing in Homogeneous Turbulence	J.F. Foss
3.	a) University of California - San Diego b) Heterogeneous Turbulent Flows Related to Propulsive Devices	Paul A. Libby
4.	a) California Institute of Technology b) Research on Turbulent Mixing	A. Roshko
5.	a) University of Colorado b) Swirling Heated Turbulent Flows as Related to Combustion Chambers	Mahinder S. Uberoi
6.	a) University of Illinois b) Turbulent Chemically Reacting Shear Flows According to Kinetic Theory Approach	Paul M. Chung

2.6 October 1, 1973 through September 30, 1974

2.6.1 Reference Reports

1. Semi-Annual Report dated October 1, 1973.
2. Semi-Annual Report dated April 1, 1974.
3. Status Report dated November, 1973.

2.6.2 Projects

No.	a) Institution b) Title	Principal Investigator
	AERODYNAMICS - FLUID MECHANICS	
1.	a) The University of Michigan b) Unsteady Transonic Flow in Two Dimensional Channels	T.C. Adamson, M. Sichel
2.	a) Pennsylvania State University b) Direct Measurement of the Unsteady Normal Force and Pitching Moment on an Axial Flow Fan Rotor Blade Element	Edgar P. Bruce
3.	a) Virginia Polytechnic Institute and State University b) An Investigation of Pressure Fluctuations and Stalling Characteristics on Rotating Axial-Flow Compressor Blades	W.F. O'Brien, H.L. Moses
4.	a) Southern Methodist University b) Fundamental Research on Relaminarization Phenomena as Produced in Nozzles and Turbines	Roger L. Simpson
5.	a) Bell Aerospace Company b) Nontangential Injection of Single and Two-Phase Jets into Subsonic Flow	G. Rudinger
6.	a) Nielsen Engineering and Research, Inc.	Jack N. Nielsen

No.	a) Institution b) Title	Principal Investigator
	b) Analytical Studies of Turbulent Separated Boundary Layers	
7.	a) United Aircraft Research Laboratories b) Analysis of the Aerodynamic Response of an Axial Compressor Blade Row Operating in a Distorted Inlet Flow	John J. Adamczyk
	TURBULENCE	
1.	a) University of California - San Diego b) Heterogeneous Turbulent Flows Related to Propulsive Devices	Paul A. Libby, F.W. Williams
2.	a) California Institute of Technology b) Research on Turbulent Mixing	A. Roshko
3.	a) University of Illinois b) Turbulent Chemically Reacting Shear Flows According to Kinetic Theory Approach	Paul M. Chung
4.	a) TRW Systems b) Turbulent Reacting Flow	F.E. Fendell
	COMBUSTION AND MOLECULAR PROCESSES	
1.	a) Massachusetts Institute of Technology b) Experimental and Theoretical Studies of Molecular Collisions and Chemical Instabilities	John Ross
2.	a) AeroChem Research Laboratories, Inc. b) High-Temperature Fast-Flow Reactor Chemical Kinetics Studies	Arthur Fontijn
3.	a) Atlantic Research Corporation b) Solid-Propellant Flame Mechanisms	A. Maček
4.	a) Calspan Corporation b) Investigation of Condensation in Flames by Scattering of Laser Radiation	J.W. Daiber

No.	a) Institution b) Title	Principal Investigator
5.	a) Yale University b) Kinetics of Phase Change and Energy Exchange	J.B. Fenn
6.	a) Massachusetts Institute of Technology b) Complex Nucleation Mechanism in Flames	J.B. Howard
7.	a) Case Western Reserve University b) A Basic Study on the Mechanism of Inflammability Limits and the Behavior of Near-Limit Flames	James S. T'ien
8.	a) AeroChem Research Laboratories b) Chemi-Ionization	Arthur Fontijn
9.	a) Massachusetts Institute of Technology b) Research on Carbon Formation in Flames	J.B. Howard
	MEASUREMENTS	
1.	a) Polytechnic Institute of New York b) Concentration and Temperature Measurements in Jets	S. Lederman
2.	a) General Electric Company b) Laser Raman Probe for Combustion Diagnostics	Marshall Lapp
3.	a) AVCO Everett Research Laboratory b) Research on the Measurements of Gas Properties in Jet Engines	D.A. Leonard

2.7 October 1, 1972 through September 30, 1973.

2.7.1 Reference Reports

1. Semi-Annual Report dated October 1, 1972.
2. Semi-Annual Report dated April 1, 1973.
3. Status Report dated November, 1972.

2.7.2 Projects

No.	a) Institution b) Title	Principal Investigator
	FLUID MECHANICS	
1.	a) University of California - San Diego b) Heterogeneous Turbulent Flows Related to Propulsive Devices	Paul A. Libby, F.A. Williams
2.	a) University of Illinois b) Turbulent Chemically Reacting Shear Flows	Paul M. Chung
3.	a) University of Michigan b) Unsteady Transonic Flows in Two Dimensional Nozzles	T.C. Adamson, M. Sichel
4.	a) Nielsen Engineering and Research, Inc. b) Analytical Studies of Turbulent Separated Boundary Layers	Jack N. Nielsen
5.	a) TRW Systems b) Turbulent Reacting Flow	F.E. Fendell
6.	a) United Aircraft Research Laboratories b) Analysis of the Aerodynamic Response of an Axial Compressor Blade Row Operating in a Distorted Inlet Flow	John J. Adamczyk, Franklin O. Carta

No.	a) Institution b) Title	Principal Investigator
7.	a) Nielsen Engineering and Research, Inc. b) Analytical Method for Predicting Turbulent Separation in Adverse Pressure Gradients	Jack N. Nielsen
8.	a) Colorado State University b) Boundary Layer Separation Studies	V.A. Sandborn, W.Z. Sadeh
	COMBUSTION AND MOLECULAR PROCESSES	
1.	a) AeroChem Research Laboratories b) Chemi-Ionization	Arthur Fontijn
2.	a) Atlantic Research Corporation b) Solid-Propellant Flame Mechanisms	A. Maček
3.	a) Calspan Corporation b) Investigation of Condensation in Flames by Scattering of Laser Radiation	J.W. Daiber
4.	a) Massachusetts Institute of Technology b) Research on Carbon Formation in Flames	J.B. Howard
5.	a) Massachusetts Institute of Technology b) Experimental and Theoretical Studies of Molecular Collisions and Chemical Instabilities	John Ross *
6.	a) Massachusetts Institute of Technology b) Molecular Interactions. Experimental and Theoretical Studies of Molecular Collisions and Transport Properties of Gases	John Ross *
7.	a) Yale University b) Kinetics of Phase Change and Energy Exchange	J.B. Fenn *
8.	a) Yale University b) Energy Exchange in Gases	J.B. Fenn *
9.	a) Brown University b) Photochemical Excitation and Ionization Ahead of Shock Waves	R.A. Dobbins

No.	a) Institution b) Title	Principal Investigator
	MEASUREMENT TECHNIQUES	
1.	a) AVCO Everett Research Laboratory	D.A. Leonard
	b) Research on the Measurements of Gas Properties in Jet Engines	
2.	a) Polytechnic Institute of Brooklyn	S. Lederman,
	b) Concentration and Temperature Measurements in Jets	P.M. Sforza
3.	a) General Electric Company	Marshall Lapp
	b) Laser Raman Probe for Combustion Diagnostics	
4.	a) Virginia Polytehnic Institute and State University	
	b) An Investigation of Pressure Fluctuations and Stalling Characteristics on Rotating Axial-Flow Compressor Blades	W.F. O'Brien, H.L. Moses

2.8 October 1, 1971 through September 30, 1972

2.8.1 Reference Reports

1. Semi-Annual Report dated October 1, 1971.
2. Semi-Annual Report dated April 1, 1972.
3. Status Report dated November, 1971.

2.8.2 Projects

No.	a) Institution b) Title	Principal Investigator
	FLUID MECHANICS	
1.	a) The University of Michigan b) Unsteady Transonic Flow in Two Dimensional Nozzles	T.C. Adamson, M. Sichel
2.	a) Nielsen Engineering and Research, Inc. b) Analytical Method for Predicting Turbulent Separation in Adverse Pressure Gradients	Jack N. Nielsen
3.	a) Colorado State University b) Boundary Layer Separation Studies	V.A. Sandborn, W.Z. Sadeh
4.	a) Purdue University b) Research on Unsteady Diffuser Flows	Alan T. McDonald
5.	a) United Aircraft Research Laboratories b) Analysis of Unsteady Aerodynamic Effects on an Axial-Flow Compressor Stage with Distorted Inflow	Franklin O. Carta
6.	a) University of California - San Diego b) Heterogeneous Turbulent Flows Related to Propulsive Devices	Paul A. Libby, F.A. Williams
7.	a) TRW Systems b) Turbulent Reacting Flow	F.E. Fendell

No.	a) Institution b) Title	Principal Investigator
8.	a) University of Illinois b) A Simplified Statistical Theory of Turbulent Chemically Reacting Shear Flows	Paul M. Chung
9.	a) Stanford University b) Properties of Particles in Two-Phase Flow Using a Laser-Doppler Technique	H.S. Seifert
	ATOMIC AND MOLECULAR COLLISIONS	
1.	a) Massachusetts Institute of Technology b) Molecular Interactions. Experimental and Theoretical Studies of Molecular Collisions and Transport Properties of Gas	John Ross
2.	a) Yale University b) Energy Exchange in Gases	J.B. Anderson, J.B. Fenn
3.	a) AeroChem Research Laboratories b) Chemi-Ionization	Arthur Fontijn
4.	a) Brown University b) Photochemical Excitation and Ionization Ahead of Shock Waves	R.A. Dobbins
5.	a) Georgia Institute of Technology b) Mass Spectrometric Study of Drift Velocities, Diffusion, and Reactions of Ions in Gases	E.W. McDaniel, D.W. Martin
6.	a) Rice University b) Measurement of Proton Affinities	J.L. Franklin
	MEASUREMENT TECHNIQUES	
1.	a) Polytechnic Institute of Brooklyn b) Concentration and Temperature Measurements in Jets	S. Lederman, P.M. Sforza
2.	a) AVCO-Everett Research Laboratory b) Research on the Measurement of Gas Properties in Jet Engines	R.M. Patrick, D.A. Leonard

No.	a) Institution b) Title	Principal Investigator
3.	a) Virginia Polytechnic Institute b) An Investigation of Pressure Fluctuations and Stalling Characteristics on Rotating Axial-Flow Compressor Blades	W.F. O'Brien, H.L. Moses
	COMBUSTION AND CHEMICAL RATE PROCESSES	
1.	a) Atlantic Research Corporation b) Solid-Propellant Flame Mechanisms	A. Maček
2.	a) Cornell Aeronautical Laboratory b) Investigation of Condensation in Flames by Scattering of Laser Radiation	J.W. Daiber
3.	a) Massachusetts Institute of Technology b) Research on Carbon Formation in Flames	J.B. Howard, B.L. Wersborg, G.C. Williams

2.9 October 1, 1970 through September 30, 1971

2.9.1 Reference Reports

1. Semi-Annual Report dated October 1, 1970.
2. Semi-Annual Report dated April 1, 1971.
3. Status Report dated February, 1971.

2.9.2 Projects

No.	a) Institution b) Title	Principal Investigator
	FLUID MECHANICS	
1.	a) AVCO-Everett Research Laboratory b) Research on the measurement of Gas Properties in Jet Engines	Donald A. Leonard
2.	a) Stanford University b) Properties of Particles in Two-Phase Flow Using a Laser-Doppler Technique	H.S. Seifert
3.	a) The University of Michigan b) Unsteady Transonic Flow in Two Dimensional Nozzles	T.C. Adamson
4.	a) Nielsen Engineering and Research, Inc. b) Analytical Method for Predicting Turbulent Separation in Adverse Pressure Gradients	Jack N. Nielsen
5.	a) Colorado State University b) Boundary Layer Separation Studies	V.A. Sandborn
6.	a) Purdue University b) Research on Unsteady Diffuser Flows	A.T. McDonald
7.	a) United Aircraft Research Laboratories b) Analysis of Unsteady Aerodynamic Effects on an Axial-Flow Compressor Stage with Distorted Inflow	Franklin O. Carta

No.	a) Institution b) Title	Principal Investigator
8.	a) University of California - San Diego b) Heterogeneous Turbulent Flows Related to Propulsive Devices	Paul A. Libby, F.A. Williams
9.	a) TRW Systems b) Turbulent Reacting Flow	F. Fendell
10.	a) Cornell Aeronautical Laboratory b) Fundamental Investigation of Nonsteady and Nonequilibrium Flow	G. Rudinger
11.	a) Martin Marietta Corporation b) Turbulent Mixing with Combustion	R.J. Sanderson
12.	a) Brown University b) Photochemical Excitation and Ionization Ahead of Shock Waves	R.A. Dobbins
13.	a) The City College of New York b) Research on Free Jet Expansion	B.B. Hamel
14.	a) Johns Hopkins University b) Local Turbulence Measurements in Turbulent Flames	Kim H. Parker
	<u>ATOMIC AND MOLECULAR COLLISIONS</u>	
1.	a) Massachusetts Institute of Technology b) Molecular Interactions. Experimental and Theoretical Studies of Molecular Collisions and Transport Properties of Gases	John Ross
2.	a) Yale University b) Energy Exchange in Gases	J.B. Anderson, J.B. Fenn
3.	a) Stanford Research Institute b) Transport Coefficients of Dissociated Gases	Henry Wise
	<u>COMBUSTION AND CHEMICAL RATE PROCESSES</u>	
1.	a) Atlantic Research Corporation b) Solid-Propellant Flame Mechanisms	A. Maček

No.	a) Institution b) Title	Principal Investigator
2.	a) Cornell Aeronautical Laboratory b) Investigation of Condensation in Flames by Scattering of Laser Radiation	G.H. Markstein
3.	a) Massachusetts Institute of Technology b) Research on Carbon Formation in Flames	J.B. Howard
4.	a) University of Denver b) Combustion Kinetics of Particulate Boron	C.M. Kelley, R.E. Williams, A. Takemoto
	CHEMI-IONIZATION AND ION-MOLECULE REACTIONS	
1.	a) AeroChem Research Laboratories b) Chemi-Ionization	Arthur Fontijn
2.	a) Georgia Institute of Technology b) Mass Spectrometric Study of Drift Velocities, Diffusion, and Reactions of Ions in Gases	E.W. McDaniel, D.W. Martin
3.	a) Rice University b) Measurement of Proton Affinities	J.L. Franklin

2.10 October 1, 1969 through September 30, 1970

2.10.1 Reference Reports

1. Semi-Annual Report dated October 1, 1969.
2. Semi-Annual Report dated May 1, 1970.

2.10.2 Projects

No.	a) Institution b) Title	Principal Investigator
	FLUID MECHANICS	
1.	a) Cornell Aeronautical Laboratory b) Fundamental Investigation of Nonsteady and Nonequilibrium Flow	G. Rudinger
2.	a) Dynamic Science b) Investigations on Nonsimilar Turbulent Boundary Development	Thomas J. Tyson
3.	a) Martin Marietta Corporation b) Turbulent Mixing with Combustion	R.J. Sanderson *
4.	a) Martin Marietta Corporation b) The Influence of Constituent Stream Properties on the Turbulent Mixing of Two-Dimensional Gas Streams	R.J. Sanderson *
5.	a) Brown University b) Ionization in the Precursor Region of a Strong Shock	R.A. Dobbins
6.	a) Stanford University b) Properties of Particles in Two-Phase Flow Using a Laser-Doppler Technique	H.S. Seifert

No.	a) Institution b) Title	Principal Investigator
7.	a) City College of the City University of New York b) Research on Free Jet Expansion	B.B. Hamel
8.	a) Massachusetts Institute of Technology b) Magnetohydrodynamics of Partially Ionized Gases	James A. Fay
	ATOMIC AND MOLECULAR COLLISIONS	
1.	a) Massachusetts Institute of Technology b) Molecular Interactions. Experimental and Theoretical Studies of Molecular Collisions and Transport Properties of Gases	John Ross
2.	a) Yale University b) Energy Exchange in Gases	J.B. Anderson, J.B. Fenn
3.	a) Stanford Research Institute b) Transport Coefficients of Reacting Gases	Henry Wise
	COMBUSTION AND CHEMICAL RATE PROCESSES	
1.	a) Atlantic Research Corporation b) Solid-Propellant Flame Mechanisms	A. Maček
2.	a) University of Denver b) Combustion Kinetics of Particulate Boron	C.M. Kelley, R.E. Williams, A. Takemoto
3.	a) Cornell Aeronautical Laboratory b) Investigation of Condensation in Flames by Scattering of Laser Radiation	G.H. Markstein
4.	a) Stanford Research Institute b) Bulk Cavitation in Monopropellants	David C. Wooten
5.	a) Massachusetts Institute of Technology b) Research on Carbon Formation in Flames	Jack B. Howard

No.	a) Institution b) Title	Principal Investigator
	CHEMI-IONIZATION AND ION-MOLECULE REACTIONS	
1.	a) AeroChem Research Laboratories b) Chemi-Ionization	Arthur Fontijn
2.	a) Georgia Institute of Technology b) Mass Spectrometric Study of Drift Velocities, Diffusion, and Reactions of Ions in Gases	E.W. McDaniel, D.W. Martin
3.	a) Rice University b) Ionic Chemistry of CO and $CO-CH_4$ Systems	J.L. Franklin

2.11 October 1, 1968 through September 30, 1969

2.11.1 Reference Reports

1. Semi-Annual Report dated October 1, 1968.
2. Semi-Annual Report dated April 1, 1969.

2.11.2 Projects

No.	a) Institution b) Title	Principal Investigator
	FLUID MECHANICS AND MHD	
1.	a) Cornell Aeronautical Laboratory b) Fundamental Investigation of Nonsteady and Nonequilibrium Flow	G. Rudinger
2.	a) Dynamic Science b) Investigations on Non-Similar Turbulent Boundary Layer Development	Irwin E. Alber
3.	a) Martin Marietta Corporation b) The Influence of Constituent Stream Properties on the Turbulent Mixing of Two-Dimensional Gas Stream	R.J. Sanderson
4.	a) Massachusetts Institute of Technology b) Magnetohydrodynamics of Paritally Ionized Gases	James A. Fay
5.	a) City College of New York b) Research on Free Jet Expansion	B.B. Hamel
6.	a) University of Illinois b) Convective Electric Discharge Phenomena	Charles E. Bond

No.	a) Institution b) Title	Principal Investigator
	ATOMIC AND MOLECULAR COLLISIONS	
1.	a) Massachusetts Institute of Technology b) Molecular Interactions. Experimental and Theoretical Studies of Molecular Collisions and Transport Properties of Gases	John Ross
2.	a) Princeton University b) Energy Exchange in Gases	J.B. Anderson, J.B. Fenn
3.	a) Stanford Research Institute b) Transport Coefficients of Reacting Gases	Henry Wise
4.	a) The University of Virginia b) Atomic and Molecular Collisions	J.E. Scott, Jr., G.D. Magnuson
	COMBUSTION AND CHEMICAL RATE PROCESSES	
1.	a) Atlantic Research Corporation b) Solid-Propellant Flame Mechanisms	A. Maček
2.	a) University of Denver b) The Combustion Kinetics of Particulate Boron	C.M. Kelley
3.	a) Cornell Aeronautical Laboratory b) Investigation of Reaction Kinetics in High-Temperature Gases	G.H. Markstein
4.	a) Cornell University b) Mechanism of Production of CN at High Temperatures and Estimates of Populations in Excited States	S.H. Bauer
	CHEMI-IONIZATION AND ION-MOLECULE REACTIONS	
1.	a) AeroChem Research Laboratories, Inc. b) Chemi-Ionization	Arthur Fontijn
2.	a) Georgia Institute of Technology b) Mass Spectrometric Study of Drift Velocities, Diffusion, and Reactions of Ions in Gases	E.W. McDaniel, D.W. Martin

No.	a) Institution b) Title	Principal Investigator
3.	a) Rice University b) Ionic Chemistry in Electron-Impact Systems and Electrical Discharges	J.L. Franklin *
4.	a) Rice University b) Ionic Chemistry in Electrical Discharges	J.L.Franklin

2.12 October 1, 1967 through September 30, 1968

2.12.1 Reference Reports

1. Semi-Annual Report dated May 1, 1968.

2.12.2 Projects

No.	a) Institution b) Title	Principal Investigator
	FLUID MECHANICS AND MHD	
1.	a) City College of New York b) Research on Free Jet Expansion	B. Hamel
2.	a) Cornell Aeronautical Laboratory, Inc. b) Fundamental Investigation of Nonsteady and Nonequilibrium Flow	G. Rudinger
3.	a) University of Illinois b) Convective Electric Discharge Phenomena	Charles E. Bond
4.	a) Massachusetts Institute of Technology b) Magnetohydrodynamics of Partially Ionized Gases	James A. Fay
	ATOMIC AND MOLECULAR COLLISIONS	
1.	a) Massachusetts Institute of Technology b) Molecular Interactions. Experimental and Theoretical Studies of Molecular Collisions and Transport Properties of Gases	John Ross
2.	a) Princeton University b) Energy Exchange in Gases	J.B. Anderson, J.B. Fenn
3.	a) Stanford Research Laboratory b) Transport Properties of Reacting Gases	Henry Wise
4.	a) University of Virginia b) Atomic and Molecular Collisions	John E. Scott, Jr.

No.	a) Institution b) Title	Principal Investigator
	COMBUSTION AND CHEMICAL RATE PROCESSES	
1.	a) Atlantic Research Corporation b) Solid-Propellant Flame Mechanisms	A. Maček
2.	a) Cornell Aeronautical Laboratory b) Investigation of Reaction Kinetics in High-Temperature Gases	G.H. Markstein
3.	a) Cornell University b) Mechanism of Production of CN at High Temperatures and Estimates of Populations	S.H. Bauer
	CHEMI-IONIZATION AND ION-MOLECULE REATIONS	
1.	a) AeroChem Research Laboratory b) Chemi-Ionization	Arthur Fontijn
2.	a) Georgia Institute of Technology b) Mass Spectrometric Study of Drift Velocities, Diffusion, and Reactions of Ions in Gases	E.W. McDaniel,
3.	a) Rice University b) Ionic Chemistry in Electrical Discharges	J.L. Franklin

<u>Contractor</u>: AEROCHEM RESEARCH LABORATORIES, INC.
Princeton, New Jersey

<u>Subject</u>: Chemi-Ionization

<u>Principal Investigator</u>: Arthur Fontijn

<u>Objective</u>: The study of the kinetics and mechanisms of chemi-ionization reactions and closely related phenomena.

<u>Significance</u>: Chemi-ions and electrons are produced in rocket motors and plumes as well as re-entry wakes. The electrons influence radar response. For design of missile systems it is crucial to know what reactions occur and to what extent they participate. Knowledge of chemi-ionization is also of importance to advanced power generation and upper atmospheric studies.

<u>Project Period</u>: 1963 - 1973

<u>SQUID Technical Reports</u>: See Pages: 3/2 - 3/3

<u>Other Publications</u>: See Under Section 3.2, Items: 17; 21; 38, 39; 53; 67; 78; 83; 93.

Contractor: AEROCHEM RESEARCH LABORATORIES, INC.
Princeton, New Jersey 08540

Subject: High-Temperature Fast-Flow Reactor Chemical Kinetics Studies

Principal Investigator: Arthur Fontijn

Objective: The elucidation of reaction mechanisms and measurements of rate coefficients of metal atom and metal oxide reactions by experiments using the fast-flow reactor technique adapted to cover the 300 to 2000 K range.

Significance: Rocket motor performance and observable properties of rocket exhausts are influenced by reactions of metal atoms and metal oxides. For design, prediction and modeling, the mechanisms and rate coefficients (with temperature dependence) of the governing reactions should be know. Quantitative knowledge of the kinetics of such reactions can also be important to the solution of other combustion problems, in the development of electronic transition chemical lasers, in studying natural, disturbed and polluted atmospheres and in re-entry flow field calculations.

Project Period: 1977 - 1979

SQUID Technical Reports: See Pages: 3/2 - 3/3

Other Publications: See Under Section 3.2, Items: 128; 149-151.

Contractor: AEROCHEM RESEARCH LABORATORIES, INC.
Princeton, New Jersey

Subject: Preparation of Manuscript on Ionization in Flames

Principal Investigator: H. F. Calcote

Objective: To critically organize the literature on the mechanism of ionization in flames and the practical implications or uses of flame ionization.

Significance: Hydrocarbon combustion flames contain ions in excess of their equilibrium value. This has important implications for radar interference effects in rocket and jet exhausts, soot formation in flames, flame ionization detectors for gas chromatography, MHD power generation from combustion and flame, and smoke detectors.

Project Period: 1977 - 1979

SQUID Technical Reports: See Pages: 3/2 - 3/3

Other Publications: None on record.

Contractor: AERONAUTICAL RESEARCH ASSOCIATES OF PRINCETON, Inc.
Princeton, New Jersey

Subject: Second-Order Closure Modeling of Turbulent Combustion

Principal Investigator: Ashok K. Varma

Objective: To develop the "typical eddy" model for the scalar probability density function and to analyze turbulence chemistry interactions using a second-order closure approach.

Significance: The interaction between turbulence and chemistry is important in determining many key design and performance parameters of combustion and propulsion systems and any predictive modeling of the flowfield has to properly account for the effects of turbulence. Many current analytical models do not do so and are inadequate in this regard. A second-order closure procedure provides a rational approach to incorporating these interactions in a flowfield calculation.

Project Period: 1976 - 1979

SQUID Technical Reports: See Page 3/4

Other Publications: See Under Section 3.2, Items: 217, 218; 239; 244, 245.

Contractor: ATLANTIC RESEARCH
A Division of the Susquehanna Corporation
Alexandria, Virginia 22314

Subject: Solid Propellant Flame Mechanisms

Principal Investigator: Andrej Maček

Objective: To determine quantitatively burning rates of single boron particles in various gaseous atmospheres up to 500 psi pressure, and to obtain an understanding of fundamentals of combustion mechanisms(s) of such particles.

Significance: Metallic boron is very attractive thermodynamically as a propellant ingredient in air-breathing propulsion systems, such as supersonic jet propulsion and air-augmented solid rockets. This study will provide fundamental information concerning the ignition and combustion mechanisms of particulate boron in support of current programs utilizing propellants loaded with boron powder.

Project Period: 1967 - 1973

SQUID Technical Reports: See Page: 3/5

Other Publications: See Under Section 3.2, Items: 10; 22; 40.

Contractor: AVCO EVERETT RESEARCH LABORATORY
Everett, Massachusetts

Subject: Research on the Measurement of Gas Properties in Jet Engines

Principal Investigators: D.A. Leonard and R.M. Patrick

Objective: To investigate in detail the causes of jet engine compressor stall at high compression rate.

Significance: Jet engines tend to stall at high compression. Knowledge of flows around compressor blades, boundary layers, vortices and turbulence, density, pressure and temperatures will provide design information to expedite optimization of efficiency.

Project Period: 1970 - 1973

SQUID Technical Reports: See Page 3/6

Other Publications: None on record.

Contractor: BELL AEROSPACE COMPANY
Buffalo, New York

Subject: Nontangential Injection of Single and Two-Phase Jets into Subsonic Flow

Principal Investigator: George Rudinger

Objective: To gain detailed understanding of penetration of gas-particle jets into a subsonic cross flow and comparison with the behavior of pure-gas jets.

Significance: Knowledge about the dynamics of injected jets is essential for the development of advanced rocket and ramjet combustion chambers, for the design of thrust vector controls and radar-signature modification of rockets and for the development of water-augmented air cushion vehicles.

Project Period: 1973 - 1975

SQUID Technical Reports: See Page 3/7

Other Publications: See Under Section 3.2, Items: 8; 24.

Contractor: BROWN UNIVERSITY
Providence, Rhode Island

Subject: Photochemical Excitation and Ionization Ahead of Shock Waves

Principal Investigator: R. A. Dobbins

Objective: To determine the factors controlling the concentration of electronically excited species ahead of a shock wave in a monatomic gas and the relationship between precursor electronic excitation and ionization.

Significance: The occurrence of electronic excitation ahead of shock waves is important to the understanding of shock and detonation wave structure. Theoretical calculations have indicated that the photoexcitation precursor becomes a much stronger effect than photoionization when the pressure is increased above 1 torr. The purpose of this research is to explore the feasibility of and to develop the techniques for the utilization of atomic absorption spectroscopy for diagnosis of shock wave precursor effects.

Project Period: 1969 - 1972

SQUID Technical Reports: See Page: 3/8

Other Publications: None on record.

Contractor: CALIFORNIA INSTITUTE OF TECHNOLOGY
Pasadena, California

Subject: Research on Turbulent Mixing

Principal Investigator: Anatol Roshko

Objective: To describe the mechanics and extent of mixing in turbulent shear flow and to develop experimental techniques for this purpose.

Significance: Information on and understanding of the physical processes occurring in turbulent mixing are needed to provide design information and test scaling laws for many engineering devices, e.g., combustion chambers in propulsive devices, chemical laser systems, ejector systems. This program addresses itself especially to the role of the organized structures in turbulent shear flow; discovered only a few years ago, these have improved our understanding of the physical processes and may hold the key to better engineering models and calculating methods.

Project Period: 1973 - 1975
1975 - 1979

SQUID Technical Reports: See Page: 3/9

Other Publications: See Under Section 3.2, Items: 99, 100; 155; 189, 190; 246; 262.

Contractor: UNIVERSITY OF CALIFORNIA - SAN DIEGO
La Jolla, California

Subject: Heterogeneous Turbulent Flows Related to Propulsive Devices

Principal Investigator: Paul A. Libby

Objective: To elucidate the processes of mass, momentum, and energy transport and of chemical reaction in internal turbulent flows relevant to propulsive devices.

Significance: Combustion in practical propulsive devices generally involves turbulent flow and significant heat release. Thus there arises in such devices an interaction between the fluid mechanical and chemical behavior of the turbulence. Our research relates to a combined experimental and theoretical effort concerned with the characteristics of turbulence involving significant density variations such as arise in combustion.

Project Period: 1970 - 1975
1975 - 1979

SQUID Technical Reports: See Pages: 3/10 - 3/11

Other Publications: See Under Section 3.2, Items: 95-98; 152-154; 188; 197; 263-265.

<u>Contractor</u>: CALSPAN (formerly Cornell Aeronautical Laboratory, Inc.) Buffalo, New York

<u>Subject</u>: Fundamental Theoretical and Experimental Investigations of Unsteady and Nonequilibrium Flow

<u>Principal Investigator</u>: George Rudinger

<u>Objective</u>: Studies of flows in which nonequilibrium effects are produced by a dispersed second phase which may be solid, liquid, or gaseous.

<u>Significance</u>: Nonequilibrium and nonsteady two-phase flows are important for various jet engines and in connection with many problems of high-speed flight. Theoretical and experimental methods are needed for the analysis of problems of two-phase flow in which a gas transports large numbers of small particles (solid, liquid, or gaseous) whose temperature and velocity are not able to follow rapid changes in the carrier gas. This study is intended to enhance the understanding of flows in which considerable deviations from equilibrium may occur when the particles represent an appreciable mass fraction of the mixture.

<u>Project Period</u>: 1967 - 1970

<u>SQUID Technical Reports</u>: See Page: 3/12

<u>Other Publications</u>: See Under Section 3.2, Item: 8.

<u>Contractor</u>: CALSPAN (formerly Cornell Aeronautical Laboratory, Inc.) Buffalo, New York

<u>Subject</u>: Investigation of Condensation in Flames by Scattering of Laser Radiation

<u>Principal Investigator</u>: J.W. Daiber and G.H. Markstein

<u>Objective</u>: To determine rates of nucleation, particle sizes, number densities and rates of growth, of condensed-phase products that form in metal-containing flames.

<u>Significance</u>: Condensation processes are relevant to the combustion process in propulsion devices that use propellants containing metals or metal compounds. The burning rate of individual metal particles depends on the structure of the reaction zone that surrounds the particle, and therefore in turn on the condensation rate of oxide particles in that zone. The presence of oxide particles in the combustion chamber and nozzle afffects radiative energy transfer, chemical kinetics and fluid dynamics.

<u>Project Period</u>: 1969 - 1973

<u>SQUID Technical Reports</u>: See Page: 3/12

<u>Other Publications</u>: See Under Section 3.2, Item: 80.

Contractor: CASE WESTERN RESERVE UNIVERSITY
Cleveland, Ohio

Subject: A Basic Study on the Mechanism of Inflammability Limits and the Behavior of Near-limit Flames

Principal Investigator: James S. T'ien

Objective: To elucidate the inflammability mechanism of premixed and diffusion flames, including extinction induced by unsteady processes.

Significance: Flammability is one of the most important problems in combustion. It is directly related to fire safety, flame spread, ignition and extinction phenomena.

Project Period: 1973 - 1975
1975 - 1976

SQUID Technical Reports: See Page 3/13

Other Publications: See Under Section 3.2, Items: 101; 139-141; 156; 234.

Contractor: CITY COLLEGE OF NEW YORK
New York, New York

Subject: Research on Free Jet Expansion

Principal Investigator: B.B. Hamel

Objective: To investigate the rarefaction effects in free jet expansion, in particular the expansion of a free jet into a region of finite back pressure.

Significance: Free jet expansion is of particular interest in connection with rocket exhaust plumes for the prediction of exhaust plume flow fields at high altitudes. An application of kinetic theory is employed to provide a quantitative understanding of the rarefaction effects in free jet expansion.

Project Period: 1967 - 1971

SQUID Technical Reports: See Page: 3/14

Other Publications: See Under Section 3.2, Items: 19; 26; 32.

<u>Contractor</u>: UNIVERSITY OF COLORADO
Boulder, Colorado 80302

<u>Subject</u>: Swirling Heated Turbulent Flows as Related to Combustion Chambers

<u>Principal Investigator</u>: Mahinder S. Uberoi

<u>Objective</u>: To experimentally study the change in turbulent mixing due to swirl and heating of jets. Measurements of mean velocity, temperature and the fluctuations will be made in non-recirculating and recirculating swirling flows. The prediction of the flow development for a swirling and chemically reacting free jet will be made analytically for various degrees of swirl. An annular swirling and chemically reacting jet in a divergent combustion chamber will also be studied.

<u>Significance</u>: Turbulence and mixing determines level of combustion efficiency, noise generation and heat transfer in swirling flows. The measurements will provide design information for combustion chambers used in turbojets, rockets and various internal combustion engines.

<u>Project Period</u>: 1974 - 1979

<u>SQUID Technical Reports</u>: See Page: 3/15

<u>Other Publications</u>: See Under Section 3.2, Items: 142-144; 158-161; 198.

Contractor: COLORADO STATE UNIVERSITY
Fort Collins, Colorado 80521

Subject: Boundary Layer Separation Studies

Principal Investigators: V.A. Sandborn and W.Z. Sadeh

Objective: Measurements of turbulent boundary layer characteristics up to and through separation.

Significance: Boundary layer separation is a limiting factor in the performance of nearly all fluid flow devices. In turbomachinery, for example, turbulent boundary layer separation is encountered in diffuser flows. The present study is being done to obtain data on the flow up to and through separation. This study is being done in conjunction with Nielsen Engineering and Research Inc. (NEAR). The experimental data is supplied to NEAR, and they are developing analytical techniques of predicting turbulent boundary layer separation.

Project Period: 1970 - 1972

SQUID Technical Reports: See Page: 3/16

Other Publications: None on record.

Contractor: COLORADO STATE UNIVERSITY
Fort Collins, Colorado

Subject: Effects of Turbulence on Flow Through an Axial Compressor Blade Cascade

Principal Investigator: Willy Z. Sadeh

Objective: To determine the effects of outer turbulence in reducing the aerodynamic losses in flow through a blade cascade of an axial-flow compressor at moderate Reynolds numbers of order of 2×10^5 or smaller.

Significance: At moderate Reynolds numbers of order of 2×10^5 or smaller prohibitively high aerodynamic losses and even fully stalled blades are induced by laminar separation of the profile boundary layer. Arresting the growth of the laminar separation bubble and even forestalling its own occurrence can be controlled by supplying oncoming turbulence of sufficient energy concentrated at scales commensurate with the thickness of the prevalent profile laminar boundary layer. Accumulation of turbulent energy at desired scales can be produced through selective amplification of turbulence. This turbulence amplification is, in turn, governed by the vortex stretching mechanism characteristic to forward stagnation flow. The research program focuses on investigating the vortex stretching mechanism for determing the characteristics of the interaction between the amplified turbulence and the body boundary layer. The ultimate goal is to put forth a predictive model regarding the management of profile laminar separation by means of the oncoming amplified turbulence.

Project Period: 1975 - 1979

SQUID Technical Reports: See Page: 3/16

Other Publications: See Under Section 3.2, Item: 283.

Contractor: CORNELL UNIVERSITY
Ithica, New York

Subject: Mechanism of Production of CN at High Temperatures and Estimates of Populations in Excited States

Principal Investigator: S. H. Bauer

Objective: To establish the mechanism of production of CN and of simple molecules which incorporate this radical, in mixtures of hydrocarbons and nitrogen (or air), as dependent on the thermal history of such samples. Technique: Record time resolved spectra in emission and absorption of shock heated mixtures; analyze mixtures subjected to single-pulse shocks by mass spectrometry and v.p.c.; correlate results with relative concentrations and total gas densities.

Significance: These studies comprise the initial steps for modelling compositions, densities and temperatures as present in rocket chambers and plumes, for the investigation of the mechanism of CN production---a radical which plays a major role in much of combustion kinetics.

Project Period: 1967 - 1969

SQUID Technical Reports: See Page: 3/17

Other Publications: None on record.

<u>Contractor</u>: CORNELL UNIVERSITY
Ithica, New York

<u>Subject</u>: Pyrolysis of Synthetic Fuels Using the Laser-Powered Homogeneous Pyrolysis Technique

<u>Principal Investigator</u>: William J. McLean

<u>Objective</u>: To examine the homogeneous pyrolysis process of hydrocarbon fuels as a function of their hydrogen content with emphasis on formation of soot precursors during pyrolysis of high carbon-to-hydrogen ratio synthetic fuels.

<u>Significance</u>: Future synthetic fuels derived from nonpetroleum fossil resources will almost certainly have a much higher carbon-to-hydrogen ratio than current fuels, mainly because of their higher aromatic content. Flame luminosity and soot formation tendencies of their fuels in jet engine combustors is intimately related to the chemical dynamics of the pyrolysis process.

<u>Project Period</u>: 1977 - 1979

<u>SQUID Technical Reports</u>: See Page: 3/17

<u>Other Publications</u>: None on record.

Contractor: UNIVERSITY OF DENVER
Denver Research Institute
Denver, Colorado

Subject: Combustion Kinetics of Particulate Boron

Principal Investigator: C. M. Kelley

Objective: To determine the reaction rate and combustion phenomena of particulate boron as a function of temperature and to compare these with data obtained by coating the particles with a relatively more reactive material.

Significance: Boron, as a potentially efficient fuel additive, will not burn efficiently at the lower temperatures associated with the lean overall fuel/air ratios required at low flight Mach numbers. One of the primary causes for the combustion inefficiency is the incomplete reaction of boron at the low engine temperature. The influence of a high temperature environment produced by coating the boron with a more reactive material is studied to assess the potential for accelerated ignition and improved combustion efficiency of the particles.

Project Period: 1969 - 1970

SQUID Technical Reports: See Page: 3/18

Other Publications: See Under Section 3.2, Item: 25.

Contractor: DYNAMIC SCIENCE
Monrovia, California

Subject: Investigation on Nonsimilar Turbulent Boundary Layer Development

Principal Investigator: Irwin E. Alber, Thomas J. Tyson

Objective: To establish a sound basis for the accurate and rapid engineering calculations of compressible and incompressible nonsimilar turbulent boundary layer development.

Significance: Knowledge of turbulent boundary layer behavior is necessary for the prediction of heat transfer, skin friction, and performance degradation due to separation in many engineering devices, e.g., rocket nozzles, engine inlets, turbine blades, and aerodynamic lifting surfaces. This program involves the development of rapid and accurate computational techniques for the analysis of high speed turbulent boundary gradients, and changes in wall temperature.

Project Period: 1969 - 1970

SQUID Technical Reports: See Page: 3/19

Other Publications: None on record.

Contractor: GENERAL ELECTRIC COMPANY
Schenectady, New York

Subject: Laser Raman Probe for Combustion Diagnostics

Principal Investigator: Dr. Marshall Lapp

Objective: To provide a scientific basis for a non-perturbing, space and time resolved optical probe of gas temperature and constituency in combustion systems.

Significance: Advanced combustion systems are utilizing pressures and temperatures such that physical probes cannot survive. Optical sensors will be useful initially for providing detailed access to temperature and species concentrations in post-combustor flow, later in the combustor itself, and may ultimately be used to provide a signal for control purposes. Application will also be to non-equilibrium gases such as found in lasers and rapid expansions.

Project Period: 1972 - 1975
1975 - 1979

SQUID Technical Reports: See Page: 3/20

Other Publications: See Under Section 3.2, Items: 102-104; 129-132; 165-169; 191; 204; 224.

Contractor: GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia

Subject: Mass Spectrometric Study of Drift Velocities, Diffusion, and Reactions of Ions in Gases

Principal Investigators: Dr. E.W. McDaniel and Dr. D.W. Martin

Objective: To measure the drift velocities and diffusion coefficients of negative ions of carbon monoxide in the parent gas and to determine the rate coefficients for reactions between these ions and carbon monoxide molecules. In addition, to make similar measurements on the ions of carbon dioxide in the parent gas.

Significance: The initial goal under the previous sub-contract with the University of Virginia was to design and build a drift tube mass spectrometer which would enable us to make accurate, quantitative studies of the behavior of mass-identified ions drifting, diffusing, and reacting in gases at thermal and supra-thermal energies at room temperature. This goal was accomplished. Under the present sub-contract with Purdue University, the apparatus was to be used to study ions in their various parent gases. At the same time, a theoretical program was to be undertaken which would provide the analysis necessary for the extraction of basic information on ionic drift, diffusion, and reactions from the raw data provided by the experiments.

Project Period: 1968 - 1971

SQUID Technical Reports: See Pages: 3/21 - 3/22

Other Publications: See Under Section 3.2, Items: 31; 34, 35; 41-43; 54-59.

Contractor: UNIVERSITY OF ILLINOIS
Urbana, Illinois

Subject: Research in Convective Electric Discharge Phenomena

Principal Investigator: C.E. Bond

Objective: Diagnostic measurements and analysis of the flow field, electric current distribution and energy transfer processes associated with the magnetically-stabilized plasma column of the supersonic electronic arc. Schlieren, Rogowski coil, and potential-probe measurements, on, as well as high-speed streak photographic acceleration studies of, stable convective plasma columns produced by the thermionic rail accelerator.

Significance: Diagnostics of the stable convective plasma column is of fundamental importance to the development of magnetoplasmadynamic propulsion systems.

Project Period: 1967-1969

SQUID Technical Reports: See Page: 3/23

Other Publications: See Under Section 3.2, Items: 12; 20.

Contractor: UNIVERSITY OF ILLINOIS AT CHICAGO CIRCLE
Chicago, Illinois

Subject: Turbulent Chemically Reacting Shear Flows

Principal Investigator: Paul M. Chung

Objective: To analyze the mixing and chemical reactions, particularly the combustion, taking place in turbulent shear flow fields. The existing phenomenolgical assumptions will be continuously replaced by a correct yet tractable theory which is applicable to engineering problems.

Significance: It has been shown that neither the existing mixing-length theories nor the recent second order moment theories can describe the turbulent chemical reactions involving many chemical species correctly. The correct description of the chemical reactions, in particular turbulent combustion, is important in analyzing the various propulsion as well as chemical-laser systems.

Project Period: 1971 - 1974

SQUID Technical Reports: See Page: None

Other Publications: See Under Section 3.2, Items: 76; 84-86.

Contractor: JOHNS HOPKINS UNIVERSITY
Baltimore, Maryland

Subject: Local Turbulence Measurements in a Turbulent Flame

Principal Investigator: K. H. Parker

Objective: To measure the local velocity and temperature fluctuations in a turbulent flame field.

Significance: Turbulence affects mixing, combustion processes, heat transfer and noise in any jet propulsion device. Knowledge of the structure and turbulent properties in a turbulent flame resulting from this study will aid substantially in the understanding of the phenomena governing the performance of these devices.

Project Period: 1969 - 1971

SQUID Technical Reports: None

Other Publications: See Under Section 3.2, Item: 28.

Contractor: KANSAS STATE UNIVERSITY
Manhattan, Kansas

Subject: Isotopic Studies of the Chemical Mechanisms of Soot Nucleation

Principal Investigators: Thomas W. Lester and Joseph F. Merklin

Objective: To determine experimentally to what extent soot nucleation occurs from heteratomic species by ring condensation and fragmentation, and to identify the kinetic paths important in each route.

Significance: Soot formation will be aggravated with the introduction of synthetic fuels. Soot formation causes an increased radiative heat load on turbine combustor liners and fouls turbine blades. Knowledge of the chemical mechanisms will help identify which thermodynamic conditions are conductive to suppressing the yield of soot from synthetic fuel constituents.

Project Period: 1978 - 1979

SQUID Technical Reports: None

Other Publications: See Under Section 3.2, Item: 266.

Contractor: MARTIN MARIETTA CORPORATION
Denver, Colorado

Subject: Turbulent Mixing with Combustion

Principal Investigator: R. J. Sanderson

Objective: To investigate the relationship between turbulent transport and the kinetics of the H_2-O_2-M reaction.

Significance: Combustion occurs in turbulent mixing regions in many practical flow situations. Examples include fuel rich propulsion system exhausts and air augmented propulsion systems. Additionally, the characteristics of rocket and jet plumes and associated heating and impingement problems can be substantially changed by the presence of exothermic reactions. This study was undertaken to obtain experimental data for two-dimensional mixing layers for streams with large velocity difference and density ratios and to examine the effects of energy liberation on the structure of the mixing layer.

Project Period: 1969 - 1970

SQUID Technical Reports: See Page: 3/24

Other Publications: See Under Section 3.2, Item: 36.

Contractor: MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Cambridge, Massachusetts

Subject: Magnetohydrodynamics of Partially Ionized Gases

Principal Investigator: J.A. Fay

Objective: To study experimentally and theoretically the mechanisms for increasing the momentum and energy of a continuum-type plasma by application of MHD forces. In a rotating, quasi-steady state plasma, the distribution of current will be measured and compared with several theoretical models.

Significance: The detailed mechanis by which Lorentz forces accelerate a plasma flow determines the performance and efficiency of MHD accelerators used to simulate hypersonic flow, MPD arcs used for propulsion, and also magnetic circuit breakers.

Project Period: 1967-1969

SQUID Technical Reports: See Pages: 3/25 - 3/31

Other Publications: None on record.

Contractor: MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Cambridge, Massachusetts

Subject: Research on Carbon Formation in Flames

Principal Investigator: J.B. Howard

Objective: To assess the importance of positive ions as nuclei for the formation of carbon particles in flames and to determine the degree to which carbon particles are charged during growth and agglomeration.

Significance: Solid carbon formed during combustion in jet engines result s in loss of operating efficiency, decreased life of flame tubes, and air pollution around airports, and it aids enemy detection and aiming devices. The proposed work is directed toward the development of a working theory to be used in designing techniques for preventing carbon formation.

Project Period: 1969 - 1973

SQUID Technical Reports: See Pages: 3/25 - 3/31

Other Publications: See Under Section 3.2, Item: 37.

Contractor: MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Cambridge, Massachusetts

Subject: Complex Nucleation Mechanisms in Flames

Principal Investigator: J. B. Howard

Objective: To identify the nucleation reactions of soot particle formation and to determine quantitatively effects of pressure, temperature, and gas composition on nucleation and growth rates.

Significance: Soot formation leads to design limitations in gas turbines, pollution of aircraft bases, carrier decks, and airports, and problems in military aircraft operation. A better understanding of soot nucleation would permit the improvement of soot-control techniques.

Project Period: 1973 - 1974

SQUID Technical Reports: See Pages: 3/25 - 3/31

Other Publications: See Under Section 3.2, Items: 60, 61.

Contractor: MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Boston, Massachusetts

Subject: Molecular Interactions: Experimental and Theoretical Studies of Molecular Collisions and Transport Properties of Gases

Principal Investigator: John Ross

Objective: Experimental and theoretical studies of molecular collisions and transport properties in gases.

Significance: Detailed experimental and theoretical studies of molecular collisions are of fundamental importance for the prediction of mechanisms and rates of chemical reactions, energy transfer problems, and transport properties. These physical and chemical properties are essential for basic understanding of problems in jet propulsion.

Project Period: 1967 - 1972

SQUID Technical Reports: See Pages: 3/25 - 3/31

Other Publications: See Under Section 3.2, Items: 2-4; 6; 13; 15, 16; 18; 23-25; 27; 29; 33; 45-48; 62; 66; 70-72; 77; 81, 82; 105-107; 133-136; 170-178.

Contractor: MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Cambridge, Massachusetts.

Subject: Experimental and Theoretical Studies of Chemical Dynamics and Chemical Instabilities.

Principal Investigator: John Ross

Objective: Experimental and theoretical studies of molecular collisions, chemical dynamics and instabilities in irreversible processes.

Significance: The study of complex systems included in combustion problems such as flames, propulsion, rockets and plumes, requires investigations directed at both molecular and macroscopic approaches. Molecular beam experiments yield information on the dynamics of chemical reactions such as reaction cross section and probabilities, rate coefficients, energy distributions of exothermicities, predictions of reaction channels, the influence of internal excitation of reactants on reaction properties, problems of energy transfer and the possibility of laser actions. In combustion systems there frequently occur couplings of reaction rates with flows, transport processes and variation of state variables such as temperature and pressure. These nonlinear couplings may lead to instabilities in which a variety of interesting phenomena may take place, such as oscillations, multiple stationary states, the formation of macroscopic spatial structures and nonlinear waves.

Project Period: 1972 - 1975
1975 - 1979

SQUID Technical Reports: See Pages: 3/25 - 3/31

Other Publications: See Under Section 3.2, Items: 192, 193; 200-203; 206-212; 235-238; 251-261.

Contractor: THE UNIVERSITY OF MICHIGAN
Ann Arbor, Michigan

Subject: Unsteady Transonic Flow in Two Dimensional Nozzles

Principal Investigators: T.C. Adamson, Jr. and M. Sichel

Objective: To study inviscid unsteady transonic nozzle flows and then to include longitudinal viscous stresses so that the formation and collapse of shocks in such flows may be studied.

Significance: The nozzle problems studied to date and those proposed, fall in the parametric range corresponding to unsteady flow in turbines and compressors of jet engines, caused by gusts, nonuniform air inlet conditions, and low frequency rotor blade motion. They are also applicable to starting and stopping flows which occur in thrustor nozzles and recoilless rifles.

Project Period: 1970 - 1975

SQUID Technical Reports: See Pages: 3/32 - 3/33

Other Publications: See Under Section 3.2, Items: 121-124.

Contractor: THE UNIVERSITY OF MICHIGAN
Ann Arbor, Michigan

Subject: Three Dimensional Transonic Flows in Compressors and Channels

Principal Investigators: Thomas C. Adamson, Jr. and Martin Sichel

Objective: To use systematic asymptotic methods to analyze three dimensional inviscid steady transonic flow through axial blade rows in turbomachinery.

Significance: Present day compressors and turbines are designed such that flows relative to the blades are transonic; this necessitates the consideration of three dimensional flow fields. The asymptotic methods of analysis used in this study allow a general study of the flow field at successive levels of approximation and definition and analysis of those regions of flow where special problems arise.

Project Period: 1975 - 1979

SQUID Technical Reports: See Pages: 3/32 - 3/33

Other Publications: See Under Section 3.2, Items: 199; 229; 241.

Contractor: MICHIGAN STATE UNIVERSITY
East Lansing, Michigan

Subject: Binary Gas Mixing

Principal Investigator: John F. Foss

Objective: To identify the role of the distinctive control variables such as an alteration of the Reynolds number $\mu\lambda/\nu$ with independent changes in μ, λ and ν, a large density difference, etc., on the molecular commingling of two gaseous species in turbulent motion.

Significance: Jet engine combustion requires the molecular commingling of air and vaporized jet fuel. The latter is a heavy hydrocarbon which results in a pronounced density difference between the two gases. The role of the turbulence is to both convectively transport the two gases into juxtaposition and to also steepen the concentration gradients by the action of the strain rate field; these basic processes are under investigation.

Project Period: 1974 - 1975
1975 - 1976

SQUID Technical Reports: See Page: 3/34

Other Publications: None on record.

Contractor: UNIVERSITY OF MISSOURI
Columbia, Missouri

Subject: A Shock Tube Study of H_2 and CH_4 Oxidation with N_2O as Oxidant

Principal Investigator: Anthony M. Dean

Objective: To determine reliable high temperature rate constants for reactions of atomic oxygen with hydrogen and methane.

Significance: Reliable high temperature values of rate constants are required to more completely characterize combustion mechanisms. This mechanistic information is required for accurate modeling studies of combustion processes.

Project Period: 1975 - 1979

SQUID Technical Reports: See Page: 3/35

Other Publications: See Under Section 3.2, Items: 239/1; 248; 275, 276.

Contractor: NIELSEN ENGINEERING & RESEARCH, INC.

Subject: Analytical Method for Predicting Turbulent Separation in Adverse Pressure Gradients

Principal Investigator: Dr. Jack N. Nielsen

Objective: To develop a method for predicting the position of turbulent separation resulting from adverse pressure gradients for two-dimensional and axisymmetric flows.

Significance: By developing good methods for estimating the turbulent separation point with adverse pressure gradients, it will be possible to alleviate or avoid unsteady inlet flow which causes compression surge in jet engines. The research has a much wider range of applicability than engine inlet applications, since it treats a basic scientific problem in its own right.

Project Period: 1970 - 1973

SQUID Technical Reports: See Page: 3/36

Other Publications: See Under Section 3.2, Item: 92.

<u>Contractor</u>: THE PENNSYLVANIA STATE UNIVERSITY
State College, Pennsylvania

<u>Subject</u>: Axial Flow Fan Stage Unsteady Performance

<u>Principal Investigator</u>: Edgar P. Bruce

<u>Objective</u>: Initially, to measure the unsteady normal force and pitching moment experienced by an axial flow fan rotor blade due to operation in a flow with a sinusoidally varying axial velocity component as a function of reduced frequency and rotor blade space-to-chord ratio, stagger angle, mean angle of incidence and design loading level. The present experimental effort includes a more detailed evaluation of the flow on the blades and an evaluation of the effect of an isolated rotor and of a rotor-stator stage on time-mean and instantaneous flow field properties. A related theoretical effort is directed toward development of an unsteady cascade pitching moment expression using Henderson's vortex representation of the flow.

<u>Significance</u>: Axial flow turbomachines operating in distorted inflow develop unsteady blade pressures, forces and moments. These unsteady quantities can cause vibration, stall and losses in efficiency and can contribute significantly to radiated noise. Measurements of the significant unsteady quantities on the blades and in the surrounding flow field are scarce and are essential to the development of models that can be used with confidence in design and analysis.

<u>Project Period</u>: 1973 - 1975
1975 - 1979

<u>SQUID Technical Reports</u>: See Page: 3/37

<u>Other Publications</u>: See Under Section 3.2, Items: 109, 110.

Contractor: POLYTECHNIC INSTITUTE OF NEW YORK
(formerly of Brooklyn)
Brooklyn, New York

Subject: Concentration Measurements in Jets

Principal Investigators: S. Lederman and P.M. Sforza

Objective: To construct a prototype apparatus utilizing the Raman effect to determine concentration and temperature in a free turbulent jet, based on the feasibility study completed in the current period. Quantitative concentration and temperature profiles in the jet are to be obtained.

Significance: The understanding of mass, momentum, and energy transport and their relation in turbulent flow is basic to advancing jet propulsion technology. Measurements of these properties, unimpaired by probe interference and independent of the state variables involved, will provide basic information for improving the means for prediction and analysis of turbulent mixing flows.

Project Period: 1971 - 1973

SQUID Technical Reports: See Page: 3/38

Other Publications: See Under Section 3.2, Items: 111-113.

Contractor: POLYTECHNIC INSTITUTE OF NEW YORK
Farmingdale, New York 11735

Subject: Concentration, Temperature and Velocity Measurements in Jets

Principal Investigator: S. Lederman

Objective: To construct a prototype apparatus utilizing the Raman Effect and an LDVM to determine concentration temperature and velocity in a free turbulent jet and flame.

Significance: The advancement in jet propulsion technology depends heavily on the ability to recognize and understand the interacting phenomena taking place. To that end, experimental data, concerning instantaneous specie concentration, temperature, velocity, spectral distribution of turbulent power density, as well as particulate concentration, is of major importance. This kind of data may provide basic information towards the advancement of the state-of-the-art.

Project Period: 1973 - 1975
1975 - 1976

SQUID Technical Reports: See Page: 3/38

Other Publications: See Under Section 3.2, Items: 179, 180; 194.

Contractor: POLYTECHNIC INSTITUTE OF NEW YORK
Farmingdale, New York

Subject: Turbulence Measurements in Jets, Flames and Combustors

Principal Investigator: S. Lederman

Objective: Development of nonintrusive diagnostic techniques applicable to jets, flames and combustors. Extend the laser Raman and LDV techniques to the extraction of turbulence information from flow fields associated with propulsion devices. Attempt at correlation of experimental data with mathematical models are being made.

Significance: The advancement of propulsion technology depends heavily on the ability to recognize, understand and control the interacting phenomena taking place in the propulsion devices. To that end, experimental data concerning specie concentration, temperature, velocity, turbulent intensity and frequency, mixedness parameters as well as particulate concentration is of major importance. This kind of data obtained nonintrusively, may provide basic information helpful in advancing the state-of-the-art.

Project Period: 1976 - 1977

SQUID Technical Reports: See Page: 3/38

Other Publications: See Under Section 3.2, Items: 213-215.

Contractor: POLYTECHNIC INSTITUTE OF NEW YORK
Farmingdale, New York

Subject: Experimental Study of Nonreactive and Reactive Turbulent Jets and Internal Combustors

Principal Investigator: S. Lederman

Objective: To continue the research effort in the field of laser diagnostics, as applied to jets flames and internal combustion systems with particular emphasis on the development of an integrated system involving LDV, CARS and Spontaneous Raman. Compare experimental data obtained by the above techniques with some existing mathematical models, and data obtained by conventional means.

Significance: The advancement of propulsion technology depends heavily on the ability to recognize, understand and control the many interacting phenomena taking place in the propulsion devices. While a number of codes have been recently developed. dealing with some of the problems encountered, most of those are idealized and need for their confirmation and even application some reliable experimental data. The latter may consist of data concerning specie concentration, temperature, velocity, turbulence intensity, diffusivity, correlation and cross-correlation parameters, as well as particulate concentration. This kind of data obtained nonintrusively, may provide basic information helpful in advancing the state-of-the-art.

Project Period: 1977 - 1979

SQUID Technical Reports: See Page: 3/38

Other Publications: See Under Section 3.2, Items: 232, 233; 267.

Contractor: PRINCETON UNIVERSITY
Princeton, New Jersey

Subject: Fundamental Studies on Turbulent Swirling Jet Ignition

Principal Investigator: William A Sirignano

Objective: The determination via experimental and theoretical studies of the effect of the swirl and turbulence on combustion, ignition, and flame stabilization in continuous flow combustors.

Significance: Turbulence and swirl drastically affect scalar transport of heat and mass in continuous combustors, thereby profoundly affecting ignition, flame stabilization, and burning characteristics. This study would lead to relevant information for the combustor designer for ramjets, turbojets, and rockets.

Project Period: 1977 - 1979

SQUID Technical Reports: See Page: 3/39 - 3/40

Other Publications: None on record.

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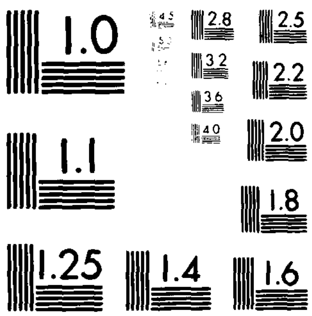

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

Contractor: PURDUE UNIVERSITY
West Lafayette, Indiana 47907

Subject: Unsteady Diffuser Flows

Principal Investigator: Alan T. McDonald

Objective: To model time-varying inlet flow distortions in the combustor diffusers of turbine engines, in order to study their effects on pressure recovery and outlet flow profiles.

Significance: Flow leaving the combustor diffusers in a turbine engine must be undistorted to obtain satisfactory combustion. Overall powerplant efficiency is affected by the pressure recovery of the combustor diffusers; they should be made as small as possible to obtain a compact engine. Theoretical predictions of these complicated internal flows are not now possible, so the empirical information obtained in this study will provide design data to help meet performance and distortion objectives with compact diffuser geometries.

Project Period: 1970 - 1971

SQUID Technical Reports: See Pages: 3/41 - 3/42

Other Publications: See Under Section 3.2, Items: 63, 64.

Contractor: RICE UNIVERSITY
Houston, Texas

Subject: Research on Chemi-ionization and Ion-Molecule Reactions in Electric Discharges

Principal Investigator: J.L. Franklin

Objective: To identify ion-molecule and chemi-ionization reactions and to determine their rates with special attention given to reactions occurring in flames.

Significance: Ions and excited neutrals undergo many extensive reactions with neutral species. They are present in great abundance in flames and in electric discharges. This study will lead to a better understanding of electric discharges and, by concentrating on reactions of certain kinds of ions, to an understanding of the chemistry of flames.

Project Period: 1967 - 1971

SQUID Technical Reports: See Pages: 3/43 - 3/44

Other Publications: See Under Section 3.2, Items: 9; 14; 23; 44; 50, 51.

Contractor: UNIVERSITY OF SHEFFIELD
Sheffield, England

Subject: The Structure of Eddies in Turbulent Flames

Principal Investigator: Norman A. Chigier

Objective: To measure the structure of turbulent flames with particular emphasis on identifying and quantifying the roles of the large eddies in these flames.

Significance: Turbulent combustion determines the rate of heat release, combustion performance and emission of pollutants in gas turbine and other forms of combustor. Understanding of the fundamental physical mechanisms of the turbulent flow with chemical reaction will aid in the solution of practical problems associated with combustion inefficiency, emission of pollutants, and over-heating of walls in combustors.

Project Period: 1977 - 1979

SQUID Technical Reports: See Page: 3/45

Other Publications: None on record.

Contractor: UNIVERSITY OF SOUTHERN CALIFORNIA
Los Angeles, California

Subject: Large Scale Structure and Entrainemnt in the Turbulent Mixing Layer

Principal Investigator: Frederick K. Browand

Objective: To improve understanding of the turbulent mixing layer by studying the interactions between the large scale, quasi-organized features.

Significance: The two-dimensional mixing region formed between parallel streams of different speed is probably the simplest example of turbulent free shear flow. It is a case of great practical importance--occurring frequently in external aerodynamics and in various combustion devices. The large scale features of the turbulence are particularly prominent in the mixing layer. A more definitive description of the dynamics of these large scale features will contribute to a better understanding of the mixing layer. The results are probably extendable to other free turbulent flows also.

Project Period: 1974 - 1975
1975 - 1979

SQUID Technical Reports: See Page: 3/46

Other Publications: See Under Section 3.2, Items: 126, 127; 230; 281, 282.

<u>Contractor</u>: SOUTHERN METHODIST UNIVERSITY
Dallas, Texas

<u>Subject</u>: Fundamental Research on Relaminarization Phenomena as Produced in Nozzles and Turbines

<u>Principal Investigator</u>: Roger L. Simpson

<u>Objective</u>: To determine the turbulence flow structure of turbulent boundary layers undergoing strong acceleration and relaminarization, especially the wall "bursting" and wall spanwise vortex structure.

<u>Significance</u>: Under a strong acceleration, a turbulent boundary layer can achieve a laminar-like character with the accompanying lower heat transfer rate of a laminar flow. Under such acceleration conditions in nozzles and turbines, a reduced heat transfer rate is desirable. Little detailed flow structure information has been previously obtained.

<u>Project Period</u>: 1973 - 1975
1975 - 1976

<u>*SQUID Technical Reports*</u>: *See Page: 3/47*

<u>Other Publications</u>: See Under Section 3.2, Item: 225.

Contractor: SOUTHERN METHODIST UNIVERSITY
Dallas, Texas

Subject: Fundamental Research on Adverse Pressure Gradient Induced Turbulent Boundary Layer Separation Using Laser Anemometry

Principal Investigator: Roger L. Simpson

Objective: To determine quantitatively the turbulence flow structure of a separating, separated, and reattached turbulent boundary layer. This information will provide new insight about the role of large eddy structures in producing separation, the role and nature of the backflow, and the interaction between the freestream and the separated flow. This information is necessary if improved prediction methods for separating flows are to be achieved.

Significance: The classical problem of adverse pressure gradient induced boundary layer separation is important in the design of jet engines and rocket nozzles. Very little quantitative information is now available on the nature of the separated flow, so current predictions of the flow downstream of separation and its interaction with the freestream are uncertain.

Project Period: 1976 - 1979

SQUID Technical Reports: See Page: 3/47

Other Publications: None on record.

Contractor: STANFORD RESEARCH INSTITUTE
Menlo Park, California

Subject: Transport Coefficients of Reacting Gases

Principal Investigator: Henry Wise

Objective/Significance: Experimental measurements of the transport coefficients of dissociated gases at elevated temperatures are lacking for systems of interest to advanced propulsion studies. To fill this gap, the work in progress in our laboratory at this time concerns the determinations of the multicomponent diffusion coefficients of dissociated gas mixtures over a range of temperatures. In addition, the results are applied to an examination of various interaction-potential functions for the description of the collision process between species with an unpaired electron (atoms, free radicals) and polyatomic molecules. Such a comparison offers some indication of the validity of the approximations made in the theoretical calculation of transport parameters by the Chapman-Enskog theory.

Project Period: 1967-1969

SQUID Technical Reports: See Pages: 3/48 - 3/49

Other Publications: See Under Section 3.2, Items: 11, 79.

Contractor: STANFORD RESEARCH INSTITUTE
Menlo Park, California

Subject: Bulk Cavitation in Monopropellants

Principal Investigator: D. C. Wooten

Objective: To determine the environemntal conditions that cause bulk cavitation and/or effervescence in liquid monopropellants, and to assess the importance of the presence of cavitation in the formation of hot spots.

Significance: The existence of cavitation-produced "hot spots" has been shown to cause detonations in liquid organic nitrate compounds and is suspected to be responsible for some accidental detonations in such monopropellants as hydrazine and nitromethane. The presence of cavitation or effervescence in liquid monopropellants permits the initiation of chemical reactions at much lower shock impulses than normally necessary to initiate a detonation in the propellants and thus presents a considerable safety hazard.

Project Period: 1969 - 1970

SQUID Technical Reports: See Pages: 3/48 - 3/49

Other Publications: None on record.

<u>Contractor</u>: STANFORD UNIVERSITY
Stanford, California

<u>Subject</u>: Properties of Particles in Two-Phase Flow Using a Laser-Doppler Technique

<u>Principal Investigators</u>: H.S. Seifert and D. Bershader

<u>Objective</u>: To simultaneously determine the distribution of velocity, number count and size of particles in a gas-particle flow.

<u>Significance</u>: The slip velocity, size distribution, and concentration of solid particles in a rocket exhaust affect performance (specific impulse). Knowledge of these quantities permits accurate performance prediction. Similar two-phase fields such as arbon-laden jet engine flow and atomized sprays can also be surveyed and mapped using the technique being developed. In addition to mapping two-phase flows, the technique can be applied to the monitering of mass flow rates of such particulates as those in jet engine or automobile exhaust. Such capability could be used for real time monitering of particulate emissions.

<u>Project Period</u>: 1969 - 1971

<u>SQUID Technical Reports</u>: See Page: 3/50

<u>Other Publications</u>: None on record.

Contractor: STANFORD UNIVERSITY
Stanford, California

Subject: Transitory Stall in Diffusers

Principal Investigator: James P. Johnston and Stephen J. Kline

Objective: Experimental study of velocity and pressure fluctuations in the transitory stall regime of a set of diffusers in order to: (i) develop basic understanding of this flow regime; (ii) provide new detailed data to allow confirmation and extension of new prediction methods (e.g., Ghose and Kline) for internal flows, with either incipient or full separation.

Significance: Gas turbine compressors, jet engine inlets and combustion systems all contain diffusers. In many instances, excess noise, combustion instabilities and even destructive mechanical vibrations are triggered by flow oscillations which may be traced to diffusers operating in the transitory stall regime. Study of this regime and discovery of means of control of its unsteadiness without sacrifice of diffuser performance is needed to advance the state of the art.

Project Period: 1976 - 1979

SQUID Technical Reports: See Page: 3/50

Other Publications: See Under Section 3.2, Items: 268-270.

Contractor: STANFORD UNIVERSITY
Stanford, California

Subject: Investigation of Novel Laser Anemometer and Particle-Sizing Instrument

Principal Investigator: Professor Sidney A. Self

Objective: Investigation and development of a laser anemometer and particle-sizing instrument capable of making simultaneous, remote, in-situ measurements of velocity and particle size in two-phase flows, with particular reference to liquid spray combustors.

Significance: The understanding of spray combustors is presently limited by our ability to measure particle concentration and size distribution as a function of position by a non-intrusive method. The ability to simultaneously measure particle size and velocity on an individual particle basis would allow the evaluation of the important influence of particle-gas slip on droplet combustion.

Project Period: 1975 - 1977

SQUID Technical Reports: See Page: 3/50

Other Publications: None on record.

Contractor: TRW SYSTEMS
Redondo Beach, California

Subject: Turbulent Reacting Flow

Principal Investigator: F.E. Fendell

Objective: To apply modern asymptotic methods (especially multiple-scaling techniques) to the analysis of fully turbulent shear layers near walls. In particular, to reveal the macroscopic structure of turbulent pipe/channel and boundary-layer flows predicted by state-of-the-art closures of the Reynolds time-averaged equations, and, further, to determine what may be stated even without an explicit closure condition.

Significance: Turbulent shear layers occur on all ducts, blades, and solid surfaces in jet engines, for large-Reynolds-number flow. The wall friction and separation of these turbulent boundary layers is critical to predicting losses from ideal performances. Furthermore, the basic fluid dynamics is a prerequisite to examining aerothermochemical phenomena in turbulent flow (for militarily practical chemical lasers, rocket chambers, jet engines, etc.). Of the hundreds of existing schemes for predicting the behavior of turbulent shear layers near walls, almost all are very minor variants on a very few physical concepts; and almost all schemes predict results with about equal success, as evidenced by the 1968tanford conference. This program seeks to avoid senselessly repetitive numerical integration of basically similar models by using modern asymptotic techniques to achieve analytic solution for broadly encompassing classes of closure conditions. In this way the essential common features of closures producing results compatible with experiments are revealed.

Project Period: 1970 - 1973

SQUID Technical Reports: See Pages: 3/51 - 3/52

Other Publications: See Under Section 3.2, Items: 69; 125.

Contractor: TRW DEFENSE AND SPACE SYSTEMS
Redondo Beach, California

Subject: The Coherent Flame Model for Turbulent Chemical Reactions

Principal Investigator: J. E. Broadwell

Objective: To develop a model for fast reactions in turbulent flow.

Significance: One of the most ambitious aims of aerothermochemistry is the rational analysis of turbulent chemical reactions. The problem arises in almost all technological combustion units and turbulent combustion processes are nearly universal in propulsion systems. Understanding of this process is essential for the systematic design of these systems as well as to the derivation of scaling laws which could give added significance to sub-scale experiments.

Project Period: 1974 - 1975
1975 - 1976

SQUID Technical Reports: See Pages: 3/51 - 3/52

Other Publications: None on record.

Contractor: UNITED AIRCRAFT RESEARCH LABORATORIES
East Hartford, Connecticut

Subject: Unsteady Aerodynamic Effects on Inlet Distortion in a Turbomachine

Principal Investigator: Franklin O. Carta

Objective: To assess the importance of including unsteady aerodynamic effects in computing the characteristics of a compressor stage operating near stall and in a distorted inlet flow.

Significance: The pressure of a non-uniform inflow can adversely affect the performance of an axial-flow compressor. The ability to predict the response of a compressor stage to a distorted inflow will increase our understanding of a compressor sensitivity to distortion phenomena and will provide us with an improved analytical tool for designing surge-tolerant compressors.

Project Period: 1970 - 1973

SQUID Technical Reports: See Page: 3/53

Other Publications: See Under Section 3.2, Item: 195.

<u>Contractor</u>: UNITED TECHNOLOGIES RESEARCH CENTER
East Hartford, Connecticut

<u>Subject</u>: Investigation of Dynamic Stall in a Cascade of Oscillating Airfoils

<u>Principal Investigator</u>: Franklin O. Carta, Arthur O. St. Hilaire

<u>Objective</u>: To conduct an experimental investigation of the effects of high aerodynamic loading on a cascade of oscillating airfoils.

<u>Significance</u>: The problem of stall flutter of turbomachinery blades has resisted solution since the earliest days of the jet age. The inability of designers to adequately account for its presence impedes the attainment of maximum engine thrust to weight ratio consistent with conservative, safe design. However, before the stall flutter problem can be attacked directly, it is necessary to investigate the more fundamental problem of dynamic stall on cascaded airfoils. Once the underlying causes and details of this problem are known, the stall flutter problem may then be attacked by a direct empirical assault, using data from this and other test programs, and by an indirect procedure in which the fundamental experimental information is used to modify and/or formulate advanced theories for heavily loaded multiblade systems.

<u>Project Period</u>: 1974 - 1975
1975 - 1979

<u>SQUID Technical Reports</u>: See Page: 3/54

<u>Other Publications</u>: See Under Section 3.2, Items: 249; 280.

Contractor: UNITED TECHNOLOGIES RESEARCH CENTER
East Hartford, Connecticut

Subject: Investigation to Extend the Applicability of Laser Raman Diagnostic Techniques to Practical Combustion Systems

Principal Investigator: Alan C. Eckbreth

Objective: With the development of high power, visible laser sources, Raman scattering techniques have received considerable attention for combustion diagnosis in the past several years. Laser Raman approaches have been advanced to the point where they are being routinely employed in a variety of fundamental flame investigations. However, successful application of laser Raman techniques to practical combustion devices such as gas turbines, hydrocarbon-fueled combustors, furnaces, has not been demonstrated. From an instrumentation view, practical devices contain flames which differ markedly from those employed in fundamental flame studies. Practical environments are turbulent, highly luminous and particulate laden. The high luminosity levels preclude the use of cw laser sources for Raman work in these environments. Pulsed laser sources are required to produce peak Raman powers in excess of the background luminous power. However, the use of pulsed sources engenders a variety of laser-particulate interaction interference effects which jeopardize successful application of Raman scattering. Of these, the most severe is laser modulated soot incandescence. Soot particles in the measurement volume absorb the incident laser radiation, heat to temperatures (4000°K) far above ambient, and emit greatly increased amounts of broadband radiation which can exceed the Raman signal levels. The objective of the investigation was to experimentally investigate this problem and to formulate potential solutions to circumvent it.

Project Period: 1976 - 1977

SQUID Technical Reports: See Page: 3/54

Other Publications: See Under Section 3.2, Item: 196.

Contractor: UNITED TECHNOLOGIES RESEARCH CENTER
East Hartford, Connecticut

Subject: CARS Investigations in Sooting Flames

Principal Investigator: Alan C. Eckbreth

Objective: To investigate the applicability of rapid Raman (CARS) thermometry to practical (i.e. turbulent, sooting) combustion environments.

Significance: Rapid temperature measurements are required to determine the temperature probability distribution functions in practical combustion devices. Such measurements will aid the understanding of turbulent combustion phenomena and enhance the accuracy of predictive modelling theories particularly in regard to pollutant levels. This investigation will examine potential nonlinear, soot interference effects in coherent anti-Stokes Raman spectroscopy (CARS) which looks very promising for practical combustor probing. If necessary, techniques will be developed and refined to suppress laser-induced soot CARS interferences. CARS temperature measurements will be performed in steady, laminar, hydrocarbon-fueled diffusion (i.e. sooting) flames using the best of the above developed techniques.

Project Period: 1977 - 1979

SQUID Technical Reports: See Page: 3/54

Other Publications: See Under Section 3.2, Items: 226-228; 247; 272-274; 279.

Contractor: UNIVERSITY OF VIRGINIA

Subject: Research on Atomic and Molecular Collisions

Principal Investigators: J.E. Scott, Jr. and G.D. Magnuson

Objective/Significance: To study, by means of atomic and molecular beam techniques, various aspects of atomic and molecular collision dynamics with particular emphasis on elastic scattering of the rare gases. Measured scattering cross sections are used for the determination of the long range interatomic forces.

Project Period: 1967 - 1969

SQUID Technical Reports: See Page: 3/55

Other Publications: None on record.

<u>Contractor</u>: VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
Blacksburg, Virginia

<u>Subject</u>: An Investigation of Pressure Fluctuations and Stalling Characteristics on Rotating Axial-Flow Compressor Blades

<u>Principal Investigators</u>: W.F. O'Brien, Jr. and H.L. Moses

<u>Objective</u>: To study the fundamental aspects of stalling and unsteady behavior in axial-flow compressors; to measure pressure and other flow variables on the rotors of turbomachines employing special instrumentation techniques; to develop calculation techniques for the prediction of off-design and separated flows in compressor blade rows.

<u>Significance</u>: Unsteady behavior in axial-flow compressors limits performance and can cause structural failure. The fundamental aspects of the unsteady flow are not well understood. Calculation techniques which can accurately predict unsteady, separated flows are needed. On-rotor measurements provide one of the best means for study of the several phenomena.

<u>Project Period:</u> 1971 - 1975
1975 - 1979

<u>SQUID Technical Reports</u>: See Page: None.

<u>Other Publications</u>: See Under Section 3.2, Items: 90, 91; 114-116; 137, 138; 181-184; 219-223; 231.

Contractor: UNIVERSITY OF WASHINGTON
Seattle, Washington

Subject: Investigation of Adverse Pressure Gradient Corner Flows

Principal Investigator: Frederick B. Gessner

Objective: To measure and analyze the local mean flow and turbulence structure in the vicinity of a streamwise corner under decelerating flow conditions.

Significance: The measurements will provide a body of three-dimensional flow data not previously available and yield insight into the nature of turbulent corner flow under adverse pressure gradient conditions. The data can also serve as a testing ground for higher-order closure models which have been formulated recently. Analysis of the data will facilitate the development of methods for predicting local flow development in various configurations with streamwise corners. In terms of jet propulsion applications, these configurations include rectangular ducts and diffusers, wing-body junctions, and vanes or stabilizers attached to a bounding surface.

Project Period: 1976 - 1979

SQUID Technical Reports: See Page: 3/56

Other Publications: See Under Section 3.2, Item: 271.

Contractor: YALE UNIVERSITY (1969-1971)
New Haven, Connecticut
and
PRINCETON UNIVERSITY (1967-1969)
Princeton, New Jersey

Subject: Relaxation Processes in Gases

Principal Investigators: J.B. Fenn and J.B. Anderson

Objective: To determine the rates at which gaseous systems in a non-equilibrium state can relax to equilibrium. In particular to measure the rate at which internal degrees of vibration and rotation can give up their energy to translation. In addition, to study rates and mechanisms of vaporization-condensation processes including nucleation.

Significance: Rates of energy exchange can have a strong influence on the efficiency of jet engines, especially at the low pressures and small scales of advanced propulsion systems. They play a vital role in such technologically important kinetic processes as chemical reaction, nucleation-condensation, and population inversions leading to laser action. Nucleation-condensation, still something of a mystery, has a direct impact on the engergy release in metal-containing fuel systems and governs many meteorological phenomena.

Project Period: 1969-1971 (Yale University)
1967-1969 (Princeton University)

SQUID Technical Reports: See Page: 3/57

Other Publications: See Under Section 3.2, Items: 1; 7.

Contractor: YALE UNIVERSITY
New Haven, Connecticut

Subject: Kinetics of Phase Change, Energy Exchange and Hydrocarbon Combustion

Principal Investigator: John B. Fenn

Objective: To determine rates and mechanism of mass and energy transfer during gas-gas and gas-surface molecular collisions. To measure rates at which energy is exchanged between internal and translational degrees of freedom in molecules. To measure absolute rates of evaporation. To study the kinetics and thermodynamics of nucleation-condensation for neutral molecules and the clustering of neutral molecules on ions. To probe combustion mechanisms.

Significance: Rates of intermolecular energy exchange and interphase mass exchange can have a profound influence on the propulsive efficiency of jet engines. They play a role in other technologically important processes including chemical reaction, heat and mass transfer, and population inversions leading to laser action. Natural and artificial meteorological phenomena also depend in large measure upon these elementary processes. Propulsion depends on combustion.

Project Period: 1970 - 1975
1975 - 1978

SQUID Technical Reports: See Page: 3/57

Other Publications: See Under Section 3.2, Items: 30; 52; 68; 117-120; 146-148; 185-187.

Contractor: YALE UNIVERSITY
New Haven, Connecticut

Subject: Turbulent Structure Determination by Ramanography

Principal Investigators: Richard K. Chang, Boa-Teh Chu

Objective: The objective of our research is to develop new spectroscopic techniques which are capable of providing fundamental information in the areas of turbulence and combustion.

Significance: Non-intrusive, instantaneous, and two-dimensional experimental data on well characterized nozzles and new measurement techniques are needed for the study of combustors, turbine and nozzle entry flows and engine exhaust flows.

Project Period: 1977 - 1979

SQUID Technical Reports: See Page: 3/57

Other Publications: See Under Section 3.2, Items: 277, 278.

3. REPORTS AND PUBLICATIONS

Project SQUID Technical Reports published over the period 1967-1979 are presented in Section 3.1.

Other (archival) publications are presented in Section 3.2.

3.1 REPORTS

1 AeroChem Research Laboratories, Inc.

1. TR No.: AC-7-PU
   "Formation of Electronically Excited Species in N-Atom/O-Atom Recombination Reactions Catalyzed by Carbon Compounds: NO [$A^2\Sigma$, $B^2\Pi$] and O [^1S]^1"
   Arthur Fontijn and Roy Ellison
   July 1968

2. TR No.: AC-8-PU
   "Chemiluminescence and Chemi-ionization in Nitrogen Atom/Oxygen Atom/Carbon Compound Reactions"
   Arthur Fontijn
   April 1969

3. TR No.: AC-9-PU
   "Chemi-ionization Reactions in the Gas Phase"
   Arthur Fontijn
   January 1970

4. TR No.: AC-10-PU
   "Chemiluminescent Emission of CO Fourth Positive Bands in Nitrogen Atom/Oxygen Atom/Reactive Carbon Compound Systems"
   Arthur Fontijn and Roy Ellison
   April 1970

5. TR No.: AC-11-PU
   "Comparison of the Absolute Quantum Yields of the Gas Phase O/NO Reaction and the Liquid Phase Luminol Oxidation Chemiluminescence Light Standards"
   Arthur Fontijn and John Lee
   December 1971

6. TR No.: AC-12-PU

   "A Review of Experimental Measurement Methods Based on Gas-Phase Chemiluminescence"

   Arthur Fontijn, Dan Golomb and Jimmie A. Hodgeson

   November 1972

7. TR No.: AC-13-PU

   "Recent Progress in Chemi-ionization Kinetics"

   Arthur Fontijn

   September 1973

8. TR No.: AC-14-PU

   "Chemi-ionization Reactions of Photo-Excited K Atoms"

   Arthur Fontijn, Paul F. Fennelly and Roy Ellison

   September 1974

9. TR No.: AC-15-PU

   "Elementary Combustion Reaction Kinetics Measurements over Large Temperature Ranges. The HTFFR Technique"

   Arthur Fontijn

   January 1976

10. TR No.: AC-16-PU

    "HTFFR Kinetics Studies of $Al + CO_2 \rightarrow AlO + CO$ from 300 to 1800 KA Non-Arrhenius Reaction"

    Arthur Fontijn and William Felder

    April 1977

2 Aeronautical Research Associates of Princeton, Inc.

1. TR No.: ARAP-1-PU

   "Modeling of Scalar Probability Density Functions in Turbulent Flames"

   Ashok K. Varma, Guido Sandri, Peter J. Mansfield

   September 1978

2. TR No.: ARAP-2-PU

   "Second-Order Closure Modeling of Variable Density Turbulent Flows"

   Ashok K. Varma, Peter J. Mansfield and Guido Sandri

   March 1979

3 Atlantic Research Corporation

1. TR No.: ARC-11-PU

   "Experimental Burning Rates and Combustion Mechanisms of Single Beryllium Particles"

   A. Macek and J.M. Semple

   August 1969

2. TR No.: ARC-12-PU

   "Combustion of Boron Particles at Atmospheric Pressure"

   A. Macek and J.M. Semple

   August 1969

3. TR No.: ARC-13-PU

   "Combustion of Boron Particles at Elevated Pressures"

   A. Macek and J.M. Semple

   June 1970

4. TR No.: ARC-14-PU

   "Combustion of Boron Particles: Experiment and Theory"

   A. Macek

   May 1972

4 Avco Everett Research Laboratory

1. TR No.: AVCO-1-PU

   "Point Measurement of Density by Laser Raman Scattering"

   Donald A. Leonard

   June 1972

5 Bell Aerospace Company

1. TR No.: BA-1-PU

   "Nontangential Injection of Single and Two-Phase Jets into Subsonic Flow"

   George Rudinger

   January 1976

6 Brown University

1. TR No.: BRN-21-PU

   "Trajectories of Shock Wave and Contact Surface in Real Shock-Tube Flow"

   H.J. Gerhardt

   March 1971

2. TR No.: BRN-22-PU

   " Spectroscopic Study of the Behavior of Zenon Behind a Shock Wave

   H. Semerjian

   May 1972

7 California Institute of Technology

1. TR No.: CIT-7-PU

   "Large Structure Dynamics and Entrainment in the Mixing Layer at High Reynolds Number"

   Paul E. Dimotakis and Garry L. Brown

   August 1975

2. TR No.: CIT-8-PU

   "An Experimental Investigation of Mixing in Two-Dimensional Turbulent Shear Flows with Applications to Diffusion-Limited Chemical Reactions"

   John H. Konrad

   May 1977

8 University of California - San Diego

1. TR No.: UCSD-1-PU

   "A Provisional Analysis of Two-Dimensional Turbulent Mixing with Variable Density"

   Paul A. Libby

   September 1972

2. TR No.: UCSD-2-PU

   "On Turbulent Flows with Fast Chemical Reactions . Part I: The Closure Problem"

   Paul A. Libby

   1972

3. TR No.: UCSD-3-PU

   "On Turbulent Flows with Fast Chemical Reactions. Part II. The Distribution of Reactants and Products Near a Reacting Surface"

   Carl H. Gibson and Paul A. Libby

   1972

4. TR No.: UCSD-4-PU

   "A Weakly Turbulent Flame with High Activation Energy"

   F.A. Williams

   July 1973

5. TR No.: UCSD-5-PU

   "Further Applications of Hot-Wire Anemometry to Turbulence Measurements in Helium-Air Mixtures"

   Richard A. Stanford and Paul A. Libby

   January 1974

6. TR No.: UCSD-6-PU

   "A Note on Favre Averaging in Variable Density Flows"

   R.W. Bilger

   May 1975

7. TR No.: UCSD-7-PU

   "The Structure of Diffusion Flames"

   R.W. Bilger

   June 1975

8. TR No.: UCSD-8-PU

   "Turbulence Interaction Effects in Turbulent Premixed Flames"

   K.N.C. Bray and P.A. Libby

   February 1976

9. TR No.: UCSD-9-PU

   "Turbulence Measurements of a Two-Dimensional Helium Jet in a Moving Airstream"

   Paul Anderson, John C. La Rue and Paul A. Libby

   July 1977

10. TR No.: UCSD-10-PU

   "Effects of Finite Reaction Rate and Molecular Transport in Premixed Combustion"

   Paul A. Libby, K.N.C. Bray and J.B. Moss

   May 1978

9 CALSPAN (Formerly Cornell Aeronautical Laboratory)

1. TR No.: CAL-95-PU

   "Study of the Reaction of Magnesium Vapor and Oxygen at the Surface of MgO Deposits by Atomic-Absorption Spectrophotometry"

   G.H. Markstein

   July 1968

2. TR No.: CAL-96-PU

   "Relaxation in Gas-Particle Flow"

   George Rudinger

   July 1968

3. TR No.: CAL-97-PU

   "Effective Drag Coefficients for Gas-Particle Flow in Shock Tubes"

   George Rudinger

   March 1969

4. TR No.: CAL-98-PU

   "Gas-Particle Flow in Convergent Nozzles at High Loading Ratios"

   George Rudinger

   July 1969

5. TR No.: CAL-99-PU

   "Particle Scattering Measurements in a Trimethylalauminum-Oxygen Diffusion Flame"

   J.W. Daiber

   April 1974

10 Case Western Reserve University

1. TR No.: CWRU-1-PU

   "Flammability Limits and the Oscillatory Burning of Solid Propellants at Low Pressure"

   A.R. Baliga and J.S. T'ien

   June 1974

2. TR No.: CWRU-2-PU

   "A Discussion on the Extinction Condition of a Diffusion Flame"

   James S. T'ien

   September 1974

3. TR No.: CWRU-3-PU

   "Flammability Study of Polymer Fuels using Opposed-Jet Diffusion Flame Technique"

   S.N. Singhal and J.S. T'ien

   August 1975

11 City College of New York

1. TR No.: CCNY-1-PU

   "Interaction of a Spnerical Source Flow with a Rarefied Atmosphere"

   J.W. Brook and B.B. Hamel

   September 1970

12 University of Colorado

1. TR No.: UC-1-PU
   "Mechanisms of Decay of Laminar and Turbulent Vortices"
   M.S. Uberoi
   December 1977

2. TR No.: UC-2-PU
   "Axial Flow in Trailing Line Vortices"
   M.S. Uberoi, Bhimsen K. Shivamoggi and Sen-Sung Chen
   June 1978

13 Colorado State University

1. TR No.: CSU-1-PU

   "Visualization Study of Vorticity Amplification in Stagnation Flow"

   Willy Z. Sadeh, Herbert J. Brauer and James A. Garrison

   November 1977

2. TR No.: (To be submitted)

   "Effect of Turbulence on Separation in Circular Cylinders"

   Willy Z. Sadeh and Herbert J. Brauer

14 Cornell University

1. TR No.: CU-1-Pu

"Mechanism of Production of CN at High Temperatures in N_2-C_2H_2 Mixtures"

S.H Bauer, Akiva Bar-Nun and David Lewis

June 1969

15 University of Denver

1. TR No.: DEN-1-PU
   "Combustion Kinetics of Particulate Boron"
   C.M. Kelley, R.E. Williams, A. Takemoto
   September 1970

16 Dynamic Science

1. TR No.: DYN-1-Pu

"Analytical Investigations of Equilibrium and Nonequilibrium Compressible Turbulent Boundary Layers"

Irwin E. Alber and Douglas E. Coats

May 1969

17 General Electric Company

1. TR No.: GE-1-PU

   "Laser Raman Probe for Flame Temperature"

   M. Lapp, C.M. Penney and R.L. St. Peters

   April 1973

2. TR No.: GE-2-PU

   "Summary of the Laser Raman Workshop on the Measurement of Gas Properties"

   Marshall Lapp and C.M. Penney

   June 1973

3. TR No.: GE-3-PU

   "Raman Band Contours for Water Vapor as a Function of Temperature"

   J.L. Bribes, R. Gaufres, M. Monan, M. Lapp and C.M. Penney

   July 1975

18 Georgia Institute of Technology

1. TR No.: GIT-2-PU

   "Reactions of H^+ in H_2 and D^+ in D_2; Mobilities of Hydrogen and Alkali Ions H_2 and D_2 Gases"

   T.M. Miller, J.Y. Moseley, D.W. Martin and E.W. McDaniel

   May 1968

2. TR No.: GIT-3-PU

   "Motion of an Ion Swarm in a Cylindrically Symmetric Drift Tube Mass Spectrometer"

   J.T. Moseley and I.R. Gatland

3. TR No.: GIT-4-PU

   "Ion Swarm Analysis involving Drift, Diffusion and Reactions"

   Ian R. Gatland

   December 1968

4. TR No.: GIT-5-PU

   "Possible Sources of Large Error in Determinations of Ion-Molecule Reaction Rates with Drift Tube-Mass Spectrometer"

   E.W. McDaniel

   September 1969

5. TR No.: GIT-6-PU

   "Mobilities and Longitudenal Diffusion Coefficients of Mass-identied Potassium Ions and Positive and Negative Oxygen Ions in Oxygen"

   R.M. Snuggs, D.J. Volz, J.H. Schummers, D.W. Martin, E.W. McDaniel

   September 1970

6. TR No.: GIT-7-PU

   "Reply to Longitudenal Diffusion Coefficients Misnamed by R.N. Varney"

   I.R. Gartland, E.W. McDaniel

   November 1970

7. TR No.: GIT-8-PU

"Tests of the Wannier Expressions for Diffusion Coefficients of Gaseous Ions in Electric Fields"

E.W. McDaniel and J.T. Moseley

November 1970

19 University of Illinois

1. TR No.: ILL-19-PU
   "Supersonic Electric Arcs in Sulfur Hexafluoride"
   Charles E. Bond and Dwight N. Wickersheim
   August 1969

2. TR No.: ILL-20-PU
   "The Sawtooth Column of the Supersonic Electric Arc in Sulfur Hexafluoride"
   Charles E. Bond
   December 1969

3. TR NO.: ILL-21-PU
   "Theory of an Electric-Current-Carrying Discontinuity Driven Through Nonconducting Gas by a Lorenz Force"
   Roger W. Gallington and Charles E. Bond
   March 1971

20 Martin-Marietta Corporation

1. TR No.: MAR-1-PU

   "Results of a Shock Tube Experiment in Compressible Turbulent Mixing"

   Richard J. Sanderson and Peter C. Steel

   March 1971

21 Massachusetts Institute of Technology

1. TR No.: MIT-43-PU
   "Solutions of Boltzmann Equation and Transport Processes"
   Rashmi C. Desai and John Ross
   June 1968

2. TR No.: MIT-44-PU
   "Some Developments of Faddeev's Theory for Reactive Scattering"
   John Ross and B.C. Eu
   October 1968

3. TR No.: MIT-45-PU
   "The Scattering of K and Cs by Several Compounds"
   E.F. Greene, L.F. Hoffman, M.W. Lee, J. Ross and C.F. Young
   November 1968

4. TR No.: MIT-46-PU
   "Elastic Scattering of Reactive Systems"
   John Ross and E.F. Greene
   January 1969

5. TR No.: MIT-47-PU
   "Quantum Theory of Reactive Scattering"
   John Ross
   January 1969

6. TR No.: MIT-48-PU
   "Non-Equilibrium Effects in Chemical Kinetics:
   John Ross
   January 1969

7. TR No.: MIT-49-PU
   "On Bimolecular Chemical Reactions in Imperfect Gases"
   Michael R. Emptage and John Ross
   March 1969

8. TR No.: MIT-50-PU

"Viscosity of Nitrogen, Helium, Hydrogen and Argon from -100 to 25 C up to 150-250 Atmospheres"

J.A. Gracki, G.P. Flynn and J. Ross

May 1969

9. TR No.: MIT-51-PU

"A Semiclassical Treatment of the Optical Model"

John Ross and R.E. Roberts

August 1969

10. TR No.: MIT-52-PU

"Relaxation in a Dilute Binary Gas Mixture"

John Ross and Raymond Kapral

September 1969

11. TR No.: MIT-53-PU

"Distorted Wave Born Series for Rotational Inelastic Scattering"

R.E. Roberts and John Ross

January 1970

12. TR No.: MIT-54-PU

"Non-Equilibrium Kinetics: Explicit Time-Dependence of Perturbed Distribution Functions and Auto-Correlation Expressions"

Raymond Kapral, Suzanne Hundson and John Ross

July 1970

13. TR No.: MIT-55-PU

"Estimate of Potential Surface for K-Cl-Cl"

Carl Neyland and John Ross

September 1970

14. TR No.: MIT-56-PU

"Kinetic Energies of Ionization Products from Collisions of AR-AR, He-HE below 220 eV c.m. Energy"

R.H. Hammond, J.M.S. Henis, E.F. Greene and John Ross

March 1971

15. TR No.: MIT-57-PU

"Analysis of Symmetry in Chemical Reactions"

Thomas F. George and John Ross

April 1971

16. TR No.: MIT-58-PU

"Instabilities in Coupled Chemical Reactions with Pressure-Dependent Rate Coefficients"

Peter J. Ortoleva and John Ross

June 1971

17. TR No.: MIT-59-PU

"Penetration of Boundary Perturbations in Unstable Chemical Systems"

Peter J. Ortoleva and John Ross

Autust 1971

18. TR No.: MIT-60-PU

"Response of Unstable Chemical Systems to External Perturbations"

Peter J. Ortoleva and John Ross

August 1971

19. TR No.: MIT-61-PU

"Local Dissipative Structures in Chemical Reactions with Heterogeneous Catalysis"

Peter J. Ortoleva and John Ross

December 1971

20. TR No.: MIT-62-PU

"Optical Model for Vibrational Relaxation in Reactive Systems"

Lise Lotte Poulsen, John Ross and Jeffrey I. Steinfield

February 1972

21. TR No.: MIT-63-PU

    "A Relation Between Reaction Probability and Inelastic Energy Transfer"

    Robert G. Gilbert and John Ross

    February 1972

22. TR No.: MIT-64-PU

    "Quasistatistical Complexes in Chemical Reactions"

    Thomas F. George and John Ross

    February 1972

23. TR No.: MIT-65-PU

    "The Interaction of Sound with Gas Phase Reactions"

    R.C. Gilbert, H.S. Hahn, P.J. Ortoleva and J. Ross

    April 1972

24. TR No.: MIT-66-PU

    "Physical Mechanisms of Carbon Formation in Flames"

    B.L. Werborg, J.B. Howard and G.C. Williams

    June 1972

25. TR No.: MIT-67-PU

    "Dependence of Reactivity on Internal and Translational Energy in K + SF_6, CCl_4 and $SnCl_4$"

    T.M. Sloan, S.Y. Tang and John Ross

    June 1972

26. TR No.: MIT-68-PU

    "Total Cross Sections for Formation of Ions from CsBr Collisions with Ar, Xe and NaBr (Ar)"

    L.G. Piper, L. Hellemans, J. Sloan and J. Ross

    July 1972

27. TR No.: MIT-69-PU

    "Light Scattering from Systems with Chemical Oscillations and Dissipative Structures"

    J.M. Deutch, S. Hudson, P.J. Orotleva and J. Ross

    July 1972

28. TR No.: MIT-70-PU
"Phase Waves in Oscillatory Chemical Reactions"
P.J. Ortoleva and J. Ross
November 1972

29. TR No.: MIT-71-PU
"Non-Equilibrium Relaxation Methods. Acoustic Effects in Transient Chemical Reactions"
P. Ortoleva, R. Gilbert and J. Ross
November 1972

30. TR No.: MIT-72-PU
"Coagulation of Carbon Particles in Premixed Flames"
B.L. Wersborg, J.B. Howard and G.C. Williams
December 1972

31. TR No.: MIT-73-PU
"Molecular Beam Study of Polyatomic Free Radical Reactions. Angular Distributions"
D.L. McFadden, E.A. McCullough, Jr., F. Kalos and J. Ross
February 1973

32. TR No.: MIT-74-PU
"Quantum Dynamical Theory of Molecular Collisions"
Thomas F. George and John Ross
February 1973

33. TR No.: MIT-75-PU
"Oscillations, Multiple Steady States and Instabilities in Illuminated Systems"
A. Nitzan and J. Ross
March 1973

34. TR No.: MIT-76-PU
"On Symmetry Properties of Reaction Coordinates"
H. Metiu, J. Ross, R.J. Silbey and T.F. George
1973

35. TR No.: MIT-77-PU
"A Comment on Fluctuations around Non-Equilibrium Steady State"
A. Nitzan and John Ross
December 1973

36. TR No.: MIT-78-PU
"Far-from Equilibirum Phenomena at Local Sites of Reaction"
K. Bimpong-Bota, P. Ortoleva and J. Ross
January 1974

37. TR No.: MIT-79-PU
"Symmetry Breaking Instabilities in Illuminated Systems"
A. Nitzan, P. Ortoleva and John Ross
January 1974

38. TR No.: MIT-80-PU
"On the Coupling Between Vibrational Relaxation and Molecular Electronic Transitions"
A. Nitzan
March 1974

39. TR No.: MIT-81-PU
"Mechanism of Chemical Instability for Periodic Precipitation Phenomena"
Michele Flicker and John Ross
March 1974

40. TR No.: MIT-82-PU
"Fluctuations and Transitions at Chemical Instabilities: The Analogy to Phase Transitions"
A. Nitzan, P. Ortoleva, J. Deutch and J. Ross
March 1974

41. TR No.: MIT-83-PU
"On A Variety of Wave Phenomena in Chemical Reactions"
Peter Ortoleva and John Ross
March 1974

42. TR No.: MIT-84-PU

"Non-Concerted Reactions and Symmetry Rules"

H. Metiu, J. Ross and T.F. George

March 1974

43. TR No.: MIT-85-PU

"Concentration and Mass Distribution of Charged Species in Sooting Flames"

B.L. Wersborg, A.C. Yeung and J.B. Howard

June 1974

44. TR No.: MIT-86-PU

"Soot Concentration and Absorption Coefficient in a Low Pressure Flame"

B.L. Wersborg, L.K. Fox and J.B. Howard

June 1974

45. TR No.: MIT-87-PU

"On Symmetry Properties of Reaction Coordinates"

H. Metiu, J. Ross, R. Silbey and T.F. George

August 1974

46. TR No.: MIT-88-PU

"Nucleation in Systems with Multiple Stationary States"

A. Nitzan, P. Ortoleva and J. Ross

September 1974

47. TR No.: MIT-89-PU; MIT-90-PU

"Experimental and Theoretical Studies of Chemical Dynamics and Instabilities in Irreversible Processes"

John Ross

June 1978

22 University of Michigan

1. TR No.: MICH-8-PU
   "Hypersonic Blunt Body Flow of Hydrogen-Oxygen Mixtures"
   Arnold Galloway and Martin Sichel
   July 1968

2. TR No.: MICH-9-PU
   "Unsteady Transonic Flows in Two-Dimensional Channels"
   T.C. Adamson, Jr.
   June 1971

3. TR No.: MICH-10-PU
   "A Study of Unsteady Transonic Flows with Shock Waves in Two Dimensional Channels"
   T.C. Adamson, Jr. and G.K. Richey
   November 1972

4. TR No.: MICH-11-PU
   "On the Matching of Solutions for Unsteady Transonic Nozzle Flows"
   T.C. Adamson, Jr., A.F. Messiter and G.K. Richey
   September 1973

5. TR No.: MICH-12-PU
   "Unsteady Radial Transonic Flow with Shock Waves"
   Martin Sichel
   September 1973

6. TR No.: MICH-13-PU
   "On the Flow Near a Weak Shock Wave Down stream of a Nozzle Throat"
   A.F. Messiter and T.C. Adamson, Jr.
   July 1974

7. TR No.: MICH-14-PU

   "Analysis of Unsteady Transonic Channel Flow with Shock Waves"

   G.K. Richey and T.C. Adamson, Jr.

   May 1975

8. TR No.: MICH-15-PU

   "Unsteady Transonic Flow with Heat Addition"

   Martin Sichel

   February 1976

9. TR No.: MICH-16-PU

   "Transonic Flow Problems in Turbomachinery"

   M. Platzer and T. Adamson

   February 1977

10. TR No.: MICH-17-PU

    "Unsteady Transonic Flows and Shock Waves in an Asymmetric Channel"

    John S.-K Chan and T.C. Adamson, Jr.

    May 1977

11. TR No.: MICH-18-PU

    "Summary of the Project Squid Workshop on Transonic Flow Problems in Turbomachinery"

    T.C. Adamson, Jr.

    July 1977

23 Michigan State University

1. TR No.: MSU-1-PU

   "An Experimental Study of the Transport of a Non-Diffusive Scalar Contaminant in the Decaying Turbulence Field of an Enclosed Chamber"

   K.C. Cornelius and John F. Foss

   April 1978

24 University of Missouri - Columbia

1. TR No.: UMO-1-PU

   "A Shock Tube Study of the Recombination of Carbon Monoxide and Oxygen Atoms"

   Anthony M. Dean and Don C. Steiner

   October 1976

2. TR No.: UMO-2-PU

   "A Shock Tube Study of the $H_2/O_2/CO/Ar$ and $H_2/N_2O/CO/Ar$ Systems"

   Anthony M. Dean, Don C. Steiner and Edward E. Wang

   June 1977

3. TR No.: UMO-3-PU

   "Shock Tube Studies of Formaldehyde Pyrolysis"

   Dean, Craig, Johnson, Schultz and Wang

   April 1978

4. TR No.: UMO-4-PU

   "Shock Tube Studies of Formaldehyde Oxidation"

   Dean, Johnson, Steiner

   January 1979

5. TR No.: UMO-5-PU

   "Shock Tube Studies of the $N_2O/CH_4/CO/Ar$ and $N_2O/C_2H_6/CO/Ar$ Systems"

   Anthony M. Dean and Ron L. Johnson

   April 1979

25 Nielsen Engineering and Research, Inc.

1. TR No.: NEAR-1-PU

   "An Analytical Method for Calculating Turbulent Separated Flows due to Adverse Pressure Gradients"

   Gary D. Kuhn and Jack N. Nielsen

   October 1971

2. TR No.: NEAR-2-PU

   "Studies of an Integral Method for Calculating Time-Dependent Turbulent Boundary Layers"

   Gary D. Kuhn and Jack N. Nielsen

   October 1973

26 The Pennsylvania State University

1. TR No.: PSU-13-PU

   "Axial Flow Rotor Unsteady Response to Circumferential Inflow Distortions"

   E.P. Bruce and R.E. Henderson

   September 1975

27 Polytechnic Institute of New York (Formerly of Brooklyn)

1. TR No.: PIB-31-PU

   "Specie Concentration and Temperature Measurements in Flow Fields"

   S. Lederman and J. Bronstein

   March 1973

2. TR No.: PIB-32-PU

   "Temperature and Concentration Measurements on an Axisymmetric Jet and Flame"

   S. Lederman and J. Bornstein

   December 1973

3. TR No.: PIB-33-PU

   "Temperature, Concentration and Velocity Measurements in a Jet and Flame"

   S. Lederman, J. Bornstein, A. Celentano and J. Glaser

   November 1974

4. TR No.: PIB-34-PU

   "Temperature, Concentration Velocity and Turbulence Measurements in Jet and Flames"

   S. Lederman, A. Celentano and J. Glaser

   March 1977

5. TR No.: PIB-35-PU

   "Application of the Integrated Raman and LDV System"

   S. Lederman and A. Celentano

   March 1978

6. TR No.: PIB-36-PU

   "Flow Field Measurement Using Raman and LDV Techniques"

   S. Lederman, A. Celentano, J. Glaser

   April 1979

28 Princeton University

1. TR No.: PR-115-PU

   "Viscous Effects on Impact Pressure Measurements in Low Density Flows at High Mach Numbers"

   J.H. Chang and J.B. Fenn

   October 1968

2. TR No.: PR-116-P

   "Intermediate Energy Molecular Beams from Free Jets of Mixed Gases"

   James B. Anderson

   January 1968

3. TR No.: PR-116-PU

   "Strand Size and Low Pressure Deflagration Limit in a Composite Propellant"

   Roy E. Cookson and John B. Fenn

   December 1968

4. TR No.: PR-117-P

   "New Methods for Producing High Energy Molecular Beams"

   J.B. Fenn and J.B. Anderson

   January 1968

5. TR No.: PR-117-PU

   "Thermal Recovery Factors in Supersonic Flows of Gas Mixtures"

   George Maise and John B. Fenn

   July 1969

6. TR No.: PR-118-P

   "Molecular Beam Experiments in the Lunar Environment"

   J.B. Fenn, D.G.H. Marsden and J.B. Anderson

   January 1968

7. TR No.: PR-118-PU

   "Theoretical Determination of the Discharge of Axisymmetric Nozzles under Critical Flows"

   S.P. Tang

   October 1969

8. TR No.: PR-119-PU

   "Species Separation by Stagnation of Argon-Helium Mixtures in Supersonic Flow"

   John H. Chang and John B. Fenn

   February 1971

9. TR No.: PR-120-PU

   "Velocity Distributions of Several Gases Scattered from High Temperature Surfaces"

   A. Cassuto, S. Tang and J.B. Fenn

   February 1971

10. TR No.: PR-121-PU

    "Some Applications of Molecular Beam Velocity Spectroscopy to Evaporation and Energy Exchange"

    S.P. Tand, R.J. Gallagher and J.B. Fenn

    October 1971

11. TR No.: PR-122-PU

    "Inviscid Free Jet Flow with Low Specific Heat Ratios"

    James B. Anderson

    January 1972

29 Purdue University

1. TR No.: PU-R1-75
   "Summary of the Second International Workshop on Laser Velocimetry"
   H.D. Thompson and W.H. Stevenson
   March 1975

2. TR No.: PU-R2-75
   "Turbulent Mixing in Non-Reactive and Reactive Flows"
   S.N.B. Murthy
   1975

3. TR No.: PU-R1-76
   "Combustion Measurements"
   R. Goulard
   December 1975

4. TR No.: PU-R2-76
   "Summary of Activities - Contracts and Reports 1946-1976"
   April 1976

5. TR No.: PU-R3-76
   "Reporting Procedure"
   Project Squid
   October 1976

6. TR No.: PU-R1-77
   "Turbulence on Internal Flows"
   S.N.B. Murthy
   May 1977

7. TR No.: PU-R1-78
   "Engine-Airframe Integration"
   S.N.B. Murthy
   April 1978

8. TR No.: PU-R2-78

"Alternative Hydrocarbon Fuels: Combustion and Chemical Kinetics"

C.T. Bowman and J. Birkeland

August 1978

9. TR No.: PU-R1-79

"Summary Report. DOD Colloquium on Gas Turbine Combustor Modeling. September 1979"

November 1979

10. TR No.: PU-R1-80

"Gas Turbine Combustor Design Problems"

Arthur H. Lefebvre

1980

30 Rice University

1. TR No.: RICE-2-P

   "Translational Energy Distribution of Electrons and Positive Ions in the Plasma of Microwave and High Frequency Discharges of He, Ne, and Ar"

   J.L. Franklin, Stanley A. Studniarz and P.K. Ghosh

   November 1967

2. TR No.: RICE-3-PU

   "Ion Molecule Reactions in a 50 Megacycle Discharge"

   Stanley A. Studniarz and J.L. Franklin

   May 1968

3. TR No.: RICE-4-PU

   "Electron Energies in Electrical Discharges Excited at Microwave Frequencies"

   J.L. Franklin and S.A. Studniarz

   June 1968

4. TR No.: RICE-5-PU

   "High Pressure Mass Spectra and Ion Chemistry of Carbon Dioxide"

   J.L. Franklin and Steven M. Schildcrout

   May 1969

5. TR No.: RICE-6-PU

   "Ion-Molecule Reactions in Hydrogen Sulfide, Methane Thiol and 2-Thiopropane"

   J.L. Franklin and W.E.W. Ruska

   May 1969

6. TR No.: RICE-7-PU

   "High Pressure Mass Spectra and Ion Chemistry of Carbon Suboxide"

   J.L. Franklin and S.M. Schildcrout

   July 1969

7. TR No.: RICE-8-PU

   "Mass Spectrometric Study of Ion-Neutral Reactions in Radiofrequency Discharges in Carbon Dioxide"

   J.G. Collins, J.L. Franklin and S.M. Schildcrout

   September 1969

8. TR No.: RICE-9-PU

   "High Pressure Ion-Molecule Reactions in Carbon Monoxide and Carbon Monoxide-Methane Mixtures"

   S.L. Chong and J.L. Franklin

   July 1970

9. TR No.: RICE-10-PU

   "Ion-Molecule Reactions of CH_4 - CD_4 Mixtures at High Pressures"

   S.L. Chong and J.L. Franklin

   March 1971

10. TR No.: RICE-11-PU

    "The Proton Affinity of Water"

    S.L. Chong, Ransom A. Myers, Jr. and J.L. Franklin

    September 1971

11. TR No.: RICE-12-PU

    "Ion-Molecule Reactions in the System CO_2-CH_4"

    S.F. Kasper and J.L. Franklin

    September 1971

12. TR No.: RICE-13-PU

    "Proton Affinities of Benzene, Toluene and the Xylenes"

    S.L. Chong and J.L. Franklin

    December 1971

31 University of Sheffield

1. TR No.: US-1-PU
   "The Structure of Eddies in Turbulent Flames"
   N.A. Chigier
   March 1979

32 University of Southern California

1. TR No.: USC-1-PU

   "The Growth of the Two Dimensional Mixing Layer from a Turbulent Boundary Layer"

   F.K. Browand and B.O. Latigo

   November 1978

33 Southern Methodist University

1. TR No.: SMU-1-PU

   "Laminariscent Turbulent Boundary Layers: Experiments on Sink Flows"

   Roger L. Simpson and D.B. Wallace

   July 1975

2. TR No.: SMU-2-PU

   "Laminarescent Turbulent Boundary Layers: Experiments in Nozzle Flows"

   R.L. Simpson and C.R. Shackleton

   February 1977

3. TR No.: SMU-3-PU

   "Summary Report on Colloquium on Flow Separation" (January 1979)

   November 1979

4. TR No.: (in preparation)

   "Measurements of a Separating Turbulent Boundary Layer"

   R.L. Simpson, Y.-T. Chew and B.G. Shigaprasad

   (1980)

34 Stanford Research Institute

1. TR No.: SRI-25-P

   "Diffusion and Heterogeneous Reaction XI. Theoretical Analysis of Nonsteady-State Kinetics"

   Y. Rajapakse and H. Wise

   November 1967

2. TR No.: SRI-26-P

   "Diffusion and Heterogeneous Reaction XII. Diffusion Coefficient Measurements of Atomic Oxygen through Various Gases"

   Robert S. Yolles and Henry Wise

   November 1967

3. TR No.: SRI-26-PU

   "The Reaction Kinetics of Gaseous Hydrogen Atoms with Graphite"

   Bernard J. Wood and Henry Wise

   September 1968

4. TR No.: SRI-27-PU

   "Diffusion Coefficient Measurements for Gas Mixture of Atomic and Molecular Hydrogen"

   K.M. Sancier and H. Wise

   March 1969

5. TR No.: SRI-28-PU

   "Transport Coefficients of Gas Mixtures of Atomic and Molecular Hydrogen"

   Henry Wise

   June 1969

6. TR No.: SRI-29-PU

   "Diffusion and Heterogeneous Reaction XIII. Measurements of O-O_2 Diffusion as a Function of Temperature"

   Henry Wise, Robert S. Yolles and Leonard McCulley

   August 1969

7. TR No.: SRI-30-PU
"Dynamic Tensile Failure of Glycerol"
David C. Erlich, David C. Wooten and Richard C. Crewdson
January 1971

35 Stanford University

1. TR No.: SU-1-PU

   "Investigation of Particle-Size Determination from the Optical Response of a Laser-Doppler Velocimeter"

   D.G. Andrews and H.S. Seifert

   February 1972

2. TR No.: SU-2-PU

   "An Optical Particle-Sizing Counter for In-Situ Measurements"

   Don Holve and Sidney Self

   January 1978

3. TR No.: SU-3-PU

   "A Wall-Flow-Direction Probe for Use in Separating and Reattaching Flows"

   J.K. Eaton, A.H. Jeans, J. Ashjaee and James P. Johnston

   November 1978

4. TR No.: (in preparation)

   "Transitory Stall in Diffusers"

   J. Ashjaee and J.P. Johnston

   June 1979

36 TRW Systems

1. TR No.: TRW-1-PU

   "Singular Perturbation and Turbulent Shear Flow Near Walls"

   Francis E. Fendell

   November 1971

2. TR No.: TRW-2-PU

   "Asymptotic Analysis of Turbulent Channel and Boundary Layer Flow"

   William B. Bush and Francis E. Fendell

   January 1972

3. TR No.: TRW-3-PU

   "Asymptotic Analysis of Turbulent Channel Flow for Mixing-Length Theory"

   William B. Bush and Francis E. Fendell

   June 1972

4. TR No.: TRW-4-PU

   "Asymptotic Analysis of Turbulent Channel Flow for Mean Turbulent Energy Closures"

   William B. Bush and Francis E. Fendell

   October 1972

5. TR No.: TRW-5-PU

   "The Effect of Strain on Diffusion Flames"

   George F. Carrier, Francis E. Fendell and Frank E. Marble

   October 1973

6. TR No.: TRW-6-PU

   "The Structure of Multiple Diffusion Flames for a Two-Step Chain Reaction"

   William B. Bush and Francis E. Fendell

   April 1973

7. TR No.: TRW-7-PU

   "On Diffusion Flames in Turbulent Shear Flows"

   William B. Bush and Francis E. Fendell

   July 1973

8. TR No.: TRW-8-PU

   "Asymptotic Analysis of the Turbulent Boundary Layer with Zero Wall Stress"

   William B. Bush and Francis E. Fendell

   October 1973

9. TR No.: TRW-9-PU

   "The Coherent Flame Model for Turbulent Chemical Reactions"

   Frank E. Marble and James E. Broadwell

   February 1977

37 United Aircraft Research Laboratories

1. TR No.: UARL-1-PU

   "Analysis of Unsteady Aerodynamic Effects on an Axial-Flow Compressor Stage with Distorted Inflow"

   Franklin O. Carta

   July 1972

2. TR No.: UARL-2-PU

   "Unsteady Fluid Dynamic Response of an Axial-Flow Compressor Stage with Distorted Inflow"

   John J. Adamczyk and Franklin O. Carta

   July 1973

38 United Technologies Research Center

1. TR No.: UTRC-1-PU

   "Unsteady Surface Flow Behavior on a Cascade of Airfoils Oscillating below Stall"

   F.O. Carta

   September 1975

2. TR No.: UTRC-2-PU

   "An Experimental Study on the Aerodynamic Response of a Subsonic Cascade Oscillating Near Stall"

   F.O. Carta

   August 1976

3. TR No.: UTRC-3-PU

   "Investigation To Extend the Applicability of Laser Raman Scattering Diagnostic Techniques to Practical Combustion Systems"

   Alan C. Eckbreth

   September 1976

4. TR No.: UTRC-4-PU

   "Techniques to Practical Combustion Systems"

   Alan C. Eckbreth

   October 1976

5. TR No.: UTRC-5-PU

   "CARS Investigations in Sooting and Turbulent Flows"

   A.C. Eckbreth

   March 1979

6. TR No.: UTRC-6-PU

   "Effect of Interblade Phase Angle, Incidence Angle and Gap-to-Chord Ratio on Cascade Pitching Stability"

   F.O. Carta

   August 1979

39 University of Virginia

1. TR No.: UVA-14-R-PU
   "Final Report 1961-1968"
   John E. Scott, Jr.
   December 1975

40 University of Washington

1. (In preparation)

   "Response Behavior of Hot Wires in Planar, Skewed Flows"

   F. Gessner, et al.

2. (In preparation)

   "Turbulent Flows in Rectangular Diffusers with Local Corner Flow Separation"

   F. Gessner, et al.

41 Yale University

1. TR No.: YALE-1-PU
"Vacuum Sublimation of Ammonium Perchlorate"
S.P. Tang and J.B. Fenn
November 1972

2. TR No.: YALE-2-PU
"On the Existence of Monofluroamine"
R.T.V. Kung and R. Roberts
February 1973

3. TR No.: YALE-3-PU
"The Rotational Relaxation of Molecular Hydrogen"
Robert J. Gallagher and John B. Fenn
June 1973

4. TR No.: YALE-4-PU
"Relaxation Rates from Time of Flight Analysis of Molecular Beams"
Robert J. Gallagher and John B. Fenn
December 1973

5. TR No.: YALE-5-PU
"A Free Jet Study of the Rotational Relaxation of Molecular Nitrogen from 300-1000° K"
Robert J. Gallagher and John B. Fenn
June 1974

6. TR No.: YALE-6-PU
"Clustering of Water on Hydrated Protons in a Supersonic Free Jet Expansion"
J.Q. Searcy and John B. Fenn
August 1974

3.2 Publications

Title and Author	Other Presentations
1. "Viscous Effects on Impact Pressure Measurements in Low Density Flows at High Mach Numbers" by J. H. Chang and F. B. Fenn	Sixth Rarefied Gas Dynamics Symposium
2. "*Elastic Scattering of Reactive Systems*" by J. Ross and E. F. Greene	International School of Physics - July 1968 (Italy)
3. "Quantum Theory of Reactive Scattering" by J. Ross	International School of Physics - July 1968 (Italy)
4. "Non-Equilibrium Effects in Chemical Kinetics" by J. Ross	International School of Physics - July 1968 (Italy)
5. "High Pressure Mass Spectra and Ion Chemistry of Carbon Dioxide" by J. L. Franklin and S. M. Schildcrout	Journal of Chemical Physics
6. "Viscosity of Nitrogen, Helium, Hydrogen and Argon from 100^{o} to 25^{o} up to 150-250 Atmosphere" by J. Ross, J. Gracki, and G. Flynn	Journal of Chemical Physics
7. "Thermal Recovery Factors in Supersonic Flows of Gas Mixtures" by George Maise and John B. Fenn	Symposium on Heat Transfer in Rarefied Gases - ASME Meeting - Los Angeles - Nov. 1969
8. "Gas-Particle Flow in Convergent Nozzles at High Loading Ratios" by George Rudinger	AIAA 8th Aerospace Science Meeting and AIAA Journal
9. "High Pressure Mass Spectra and Ion Chemistry of Carbon Suboxide" by J. L. Franklin and Steven M. Shildcrout	Journal of the American Chemical Society

	Title and Author	Other Presentations
10.	"Combustion of Boron Particles at Atmospheric Pressure" by Andrej Macek and . McKenzie Semple	Combustion Science and Technology Journal AIAA 5th Propulsion Joint Specialist Conference
11.	"Diffusion and Heterogeneous Reaction XIII Measurements of $O-O_2$ Diffusion As a Function of Temperature" by Robert S. Yolles, Leonard McCulley and Henry Wise	Journal of Chemical Physics
12.	"Supersonic Electric Arcs in Sulfur Hexafluoride" by Dwight N. Wickersheim and Charles E. Bond	AIAA Journal
13.	"A Semiclassical Treatment of the Optical Model" by R. E. Roberts and John Ross	Journal of Chemical Physics
14.	"Mass Spectrometric Study of Ion-Neutral Reactions in Radio-frequency Discharges in Carbon Dioxide" by Steven M. Shildcrout, J. G. Collins, and J. L. Franklin	Journal of Chemical Physics
15.	"Relaxation in a Dilute Binary Gas Mixture" by Raymond Kapral and John Ross	Journal of Chemical Physics
16.	"Possible Sources of Large Error in Determinations of Ion-Molecule Reaction Rates with Drift Tube-Mass Spectrometers" by Earl W. McDaniel	Gaseous Electronics Conference
17.	"Chemi-Ionization Reactions in the Gas Phase" by Arthur Fontijn	Progress in Reaction Kinetics, Vol. 6
18.	"Distorted Wave Born Series for Rotational Inelastic Scattering" by R. E. Roberts and John Ross	Journal of Chemical Physics

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Title and Author	Other Presentations
19. "Theoretical Determination of the Discharge Coefficients of Axisymmetric Nozzles under Critical Flows" by S. P. Tang	Journal of Fluid Mechanics
20. "The Sawtooth Column of the Supersonic Electric Arc in Sulfur Hexafluoride" by Charles E. Bond	AIAA Journal
21. "Chemiluminescent Emission of CO Fourth Positive Bands in Nitrogen Atom/Oxygen Atom/Reactive Carbon Compound Systems" by Arthur Fontijn	Journal of Chemical Physics (1970)
22. "Combustion of Boron Particles at Elevated Pressures" by Andrej Macek and J. McKenzie Semple	13th International Combustion Symposium (1970)
23. "High Pressure Ion-Molecule Reactions in Carbon Monoxide and Carbon Monoxide-Methane Mixtures" by Shuang-Ling Chong and J. L. Franklin	Journal of Chemical Physics
24. "Non-Equilibrium Kinetics: Explicit Time-Dependence of Perturbed Distribution Functions and Auto-correlation Expressions" by R. Kapral, S. Hudson and J. Ross	Journal of Chemical Physics (1970)
25. "Combustion Kinetics of Particulate Boron" by C. Kelley, R. Williams and A. Takemoto	2nd International Pyrotechnics Seminar (1970)
26. "Interaction of a Spherical Source Flow with a Rarefied Atmosphere" by J. W. Brook and B. B. Hamel	7th International Symposium on Raried Gases (1970)
27. "Estimate of Potential Surface for K-Cl-Cl" by Carl Nyeland and John Ross	Journal of Chemical Physics (1970)

Title and Author	Other Presentations
28. "The History of Velocity Waves in a Reacting Fluid" by K. Parker and J. Cavelle	AIAA Paper 70-146 (1970)
29. "Potential Inversion for the Semiclassical Optical Model" by R. Roberts and J. Ross	Journal of Chemical Physics (1970)
30. "Species Separation by Stagnation of Argon-Helium Mixtures in Supersonic Flow" by J. Fenn and J. Chang	7th International Symposium of Rarefied Gas Dynamics (1970), Italy
31. "Electronic and Ionic Impact *Phenomana*" by E. McDaniel	American Journal of Physics (1970)
32. "Exhaust Plume Rarefaction" by Muntz, Hamel, and Maguire	AIAA *Journal*, (1970)
33. "Pole Contributions in the Distorted Wave Born Series *for Inelastic* Scattering" by R. Roberts and J. Ross	Journal of Chemical Physics (1970)
34. "Ion-Molecule Reaction Between O^- and O_2 at Thermal Energies and Above" by R. Snuggs, D. Volz, I. Gatland, J. Schummers, D. Martin and E. McDaniel	Physical Review
35. "Drift Tube Studies of the Transport Properties and Reactions of Slow *Ions in* Gases" by E. McDaniel	Case Studies in Atomic Collison Physics I (1969)
36. "Measurement of Physical Properties and Growth Rate in a Burning Supersonic Mixing Layer" by R. Sanderson and P. Steel	Combustion Institute WSS/CI Paper 70-16, (1970)

Title and Author	Other Presentations
37. "Electrical Charge of Carbon Particles in Flames" by J. Howard and R. Ball	13th International Combustion Symposium (1970) and (The Combustion Institute)
38. "Chemi-Ionization Reactions in the Gas Phase," by Arthur Fontijn	Progress in Reaction Kinetics, Vol. 6
39. "Chemiluminescent Emission of CO Fourth Positive Bands in Nitrogen Atom/Oxygen Atom/Reactive Carbon Compound Systems. Relation to Chemi-Ionization" by Arthur Fontijn, Roy Ellison, William H. Smith and James Hesser	Journal of Chemical Physics, Vol. 54
40. "Combustion of Boron Particles at Elevated Pressures," by Macek, Andrej and Semple, J. Mckenzie	13th International Combustion Symposium (1970)
41. "Mobilities and Longitudinal Diffusion Coefficients of Mass-Identified Potassium Ions and Positive and Negative Oxygen Ions in Oxygen," by R.M. Snuggs, D.J. Volz, J.H. Schummers, D.W. Martin, and E.W. McDaniel	Physical Review, Vol. 3
42. "Reply to 'Longitudinal Diffusion Coefficients Misnamed,' by R.N. Varney," by I.R. Gatland and E.W. McDaniel	Phys. Rev. Letters, Vol. 25
43. "Tests of the Wannier Expressions for Diffusion Coefficients of Gaseous Ions in Strong Electric Fields," by E.W. McDaniel and J.T. Moseley	Physical Review, Vol. 3
44. "Kinetic Energies of Ionization Products from Collisions of Ar-Ar, He-He Below 220 eV c.m. Energy" by R.H. Hammond, J.M.S. Henis and E.F. Greene.	Journal of Chemical Physics
45. "Analysis of Symmetry in Chemical Reactions," by T.F. George and J. Ross	Journal of Chemical Physics

Title and Author	Other Presentations
46. "Instabilities in Coupled Chemical Reactions with Pressure-Dependent Rate Coefficients," by P. Ortoleva and J. Ross	Journal of Chemical Physics
47. "Penetration of Boundary Perturbations in Unstable Chemical Systems," by P. Ortoleva and J. Ross	Journal of Chemical Physics
48. "Response of Unstable Chemical Systems to External Perturbations," by P. Ortoleva and J. Ross	Journal of Chemical Physics
49. "Ion-Molecule Reactions of CH_4-CD_4 Mixtures at High Pressures," by Shuang-Ling Chong and J.L. Franklin	Journal of Chemical Physics
50. "The Proton Affinity of Water," by Shuang-Ling Chong, A. Ransom, Jr. and J.L. Franklin	Journal of Chemical Physics
51. "Ion-Molecule Reactions in the System CO_2-CH_4," by S.F. Kasper and J.L. Franklin	Journal of Chemical Physics
52. "Some Applications of Molecular Beam Velocity Spectroscopy to Evaporation and Energy Exchange," by S.P. Tang, R.J. Gallagher and J.B. Fenn	3rd International Symposium on Molecular Beams (France)
53. "Mechanism of Chemiluminescent Emission of the CO Fourth Positive Bands in Active Nitrogen CO Mixtures," by Arthur Fontijn and Roy Ellison	Journal of Chemical Physics, Vol. 54
54. "Ion-Molecule Reactions Between O^- and O_2 at Thermal Energies and Above," by R.M. Snuggs, D.J. Volz, I.R. Gatland, J.H. Schummers, D.W. Martin, and E.W. McDaniel	Physical Review
55. "Suggested Use of the Known Mobility of K^+ Ions in Nitrogen Gas for Pressure Calibration in Atomic Collisions Experiments," by E.W. McDaniel and D.W. Martin	Rev. Sci. Instr.
56. "Mobilities and Longitudinal Diffusion Coefficients of Mass-Identified Potassium and Nitric Oxide Ions in Nitric Oxide," by D.J. Volz, J.H. Schummers, R.D. Laser, D.W. Martin and E.W. McDaniel	Phsyical Review

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57.	"Review of 'Electronic and Ionic Impact Phenomena, Vols. I and II' by Massey and Burhop," by E.W. McDaniel	Amer. J. Phys.
58.	"Review of 'Introduction to the Theory of Ion-Atom Collisions', by M.R.C. McDowell and J.P. Coleman," by E.W. McDaniel	Amer. J. Phys.
59.	" Ion-Molecule Reactions" by E.W. McDaniel, V. Cermak, A. Dalgarno, E.E. Ferguson, and L. Friedman	John Wiley & Sons, Inc. New York
60.	"Case Studies in Atomic Collision Physics, Vol. II", edited by E.W. McDaniel and M.R.C. McDowell	North-Holland Pub. Co. Amsterdam
61.	"Electrical Charge of Carbon Particles in Flames," by J.B. Howard and R.T. Ball	Thirteenth Symposium (International) on Combustion
62.	"Direct Interaction Theory of Reactive Molecular Collisions: $K + Br_2$ System" by B.C. Eu, J.H. Huntington and J. Ross.	Canadian Journal of Physics
63.	"Behavior of Diffusers with Distorted and Unsteady Inlet Conditions," by A.T. McDonald and P.W. Runstadler, Jr.	Project SQUID Workshop on Unsteady Boundary Layers
64.	"Design and Construction of a Water Table for the Study of High Reynolds Number Diffuser Flow," by R.J. Swift	MS Thesis, Purdue University
65.	"Proton Affinities of Benzene, Toluene, and the Xylenes," by Shuang-Ling Chong and J.L. Franklin	Journal of the American Chemical Society
66.	"Local Dissipative Structures in Chemical Reactions with Heterogeneous Catalysis," by P. Ortoleva and J. Ross	Journal of Chemical Physics
67.	"Comparison of the Absolute Quantum Yields of the Gas Phase O/NO Reaction and the Liquid Phase Luminol Oxidation Chemiluminescence Light Standards," by Arthur Fontijn and John Lee	Journal of Chemical Physics
68.	"Inviscid Free Jet Flow with Low Specific Heat Ratios," by James B. Anderson	AIAA Journal
69.	"Asymptotic Analysis of Turbulent Channel and Boundary Layer Flow," by William B. Bush and Francis E. Fendell	Journal of Fluid Mechanics

Title and Author	Other Presentations
70. "Optical Model for Vibrational Relaxation in Reactive Systems," by Lise Lotte Poulsen, Jeffrey I. Steinfield and John Ross	Journal of Chemical Physics
71. "A Relation Between Reaction Probability and Inelastic Energy Transfer," by Robert G. Gilbert and John Ross	Journal of Chemical Physics
72. "Quasistatistical Complexes in Chemical Reactions," by Thomas F. George and John Ross	Journal of Chemical Physics
73. "Fluid Dynamics of Unsteady, Three-Dimensional and Separated Flows". Proceedings of a Workshop held at the Georgia Institute of Technology on June 10-11, 1971, edited by F.J. Marshall.	
74. "Aeroelasticity in Turbomachines". Proceedings of a Workshop held at Detroit Diesel Allison, Indianapolis, on June 1-2, 1972, edited by S. Fleeter.	
75. "The Use of the Laser Doppler Velocimeter for Flow Measurements". Proceedings of a Workshop held at Purdue University on March 9-10, 1972, edited by W.H. Stevenson and H.D. Thompson.	
76. "Turbulent Diffusion Flame in Couette Flow", by P.M. Chung	AIAA Preprint, No. 72-214
77. "Analysis of Symmetry in Chemical Reactions", by John Ross and Thomas F. George	Journal of Chemical Physics 55, 3851 (1971)
78. "Tubular Fast-Flow Reactor Studies at High Temperatures, I. Kinetics of the Fe/O_2 Reaction at 1600 K", by Arthur Fontijn and S.C. Kurzius	Chemical Physics Letters
79. "Transport Coefficients of Gas Mixtures of Atomic and Molecular Hydrogen," by H. Wise	Chemical Physics Letters
80. "Structure of Low-Pressure Trimethylabriminum-Oxygen Flat Diffusion Flames," by George H. Markstein	Combustion Science and Technology

Title and Author	Other Presentations
81. "Local Structures in Chemical Reactions with Heterogeneous Catalysis," by Peter Ortoleva and John Ross	Journal of Chemical Physics, Vol. 56, No. 9
82. "Molecular Beam Study of Polyatomic Free Radical Reactions. CH_3+Cl_2 and Br_2," by D.L. McFadden, E.A. McCullough, Jr., F. Kalos, W.R. Gentry, and J. Ross	Journal of Chemical Physics Vol. 57, No. 3
83. "Chemi-Ionization Reactions in a Gas Phase," by A. Fontijn	Progress in Reaction Kinetics 6, 75 (1972)
84. "Diffusion Flame in Homolgous Turbulent Shear Flows," by P.M. Chung	Physics of Fluids 15, 1735 (1972)
85. "Turbulence Description of Couette Flow," by P.M. Chung	Physics of Fluids
86. "Transport Process in Turbulent Flow Fields with Two Dynamically Significant Scales," by R.J. Bywater and P.M. Chung	AIAA 6th Fluid and Plasma Dynamics Conference, July 1973
87. "On the Performance of Turbulent Chemical Laser," by P.M. Chung	AIAA Journal
88. "Chemical Oscillations and Multiple Steady States due to Variable Boundary Permeability," by J. Ross, H. Hahn and P. Ortoleva	J. Theoretical Biology
89. "History of Physical Chemistry in Cambridge, Massachusetts," by J. Ross and E.B. Wilson	Annual Reviews of Physical Chemistry
90. "Instrumentation for Flow Measurements in Turbomachine Rotors," by W.F. O'Brien and H.L. Moses	ASME Paper No. 72-GT-55
91. "Pressure Measurements on the Rotating Blades of an Axial-Flow Compressor," by M.[illegible] Sexton, W.F. O'Brien and H.L. Moses	ASME Paper No. 73-GT-79
92. "Prediction of Turbulent Separated Boundary Layers," by Gary D. Kuhn	AIAA 6th Fluid and Plasma Dynamics Conference, July (1973)
93. "Homogeneous and Teterogeneous Kinetics of the Atomic Al/O_2 Reaction in the 1000-1700 K Range," by. A. Fontijn, W. Felder and J.J. Houghton	Fifteenth Symposium (International) on Combustion

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94. "Fundamentals and Applications of Gas-Particle Flow," by G. Rudinger	Fluid Dynamics Panel (AGARD) Rome, Italy, Septmeber 1974
95. "On Turbulent Flows with Fast Chemical Reactions, Part III: Two-Dimensional Mixing with Highly Dilute Reactants," by P.A. Libby	Combustion Science and Technology
96. "Further Applications of Hot-Wire Anemometry to Measurements in Helium-Air Mixtures," by R.A. Stanford and P.A. Libby	Phy. of Fluids
97. "A Review of Some Theoretical Considerations of Turbulent Flame Structure," by F.A. Williams	Propulsion and Energetics Panel (Agard) Leige, Belgium, April 1974
98. "Studies Related to Turbulent Flows Involving Fast Chemical Reactions," by P.A. Libby	Propulsion and Energetics Panel (AGARD) Leige, Belgium, April 1974
99. "Ideas About Free Shear Flow Structures from Experiments on Turbulent Mixing Layers," by A. Roshko	Colloquium on Coherent Structures in Turbulence, Univ. of Southhampton, March 1974
100. "Progress and Problems in Understanding Turbulent Shear Flows," by A. Roshko	SQUID Workshop on Turbulent Mixing, Purdue University, May 1974
101. "A Theoretical Criterion for Dynamic Extinction of Solid Propellants by Fast Depressurization," by J.S. T'ien	Combustion Science and Technology 9, 37 (1974)
102. "Comments on the Laser Raman Workshop on the Measurement of Gas Properties," by M. Lapp and C.M. Penney	GE Research and Development Report No. 74CRD064, May 1974
103. "Measurements and Gas Properties: Comments on the Laser Raman Workshop," by M. Lapp and C.M. Penney	Appl. Optics, 13 A14 (1974)
104. Laser Raman Gas Diagnostics, Ed. by M. Lapp and C.M. Penney	Plenum Press, New York (1974)
105. "Studies in Dissipative Phenomena with Biological Applications," by P. Ortoleva and J. Ross	Advances in Chem. Phys. (1974)
106. "On Symmetry Properties of Reaction Coordinates," by Horia Metiu, John Ross and Robert Silbey	J. Chem. Phys. (1974)

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107. "Nucleation in Systems with Multiple Stationary States," by A. Nitzan, P. Ortoleva and J. Ross	Discussions of Faraday Society on Chemical Instabilities, London
108. "The ARL Axial-Flow Research Fan--A New Facility for Investigation of Time-Dependent Turbomachinery Flows," by E.P. Bruce	ASME Paper No. 74-FE-27, (1974)
109. "Design and Evaluation of Screens to Produce Multi-Cycle ± 20% Amplitude Sinusoidal Velocity Profiles," by E.P. Bruce	AIAA Paper No. 74-623, 1974
110. "Effect of Blade Row Geometry on Axial Flow Rotor Unsteady Response to Inflow Distortions," by R.E. Henderson and E.P. Bruce	Project SQUID Workshop on Unsteady Flows in Jet Engines, 1974
111. "Application of Raman Effect to Flowfield Diagnostics," by S. Lederman and J. Bornstein	Progress in Astronautics and Aeronautics, 34, 1974
112. "Temperature and Specie Concentration Measurements in a Flow Field," by S. Lederman, M.H. Bloom, J. Bornstein and P.K. Khosla	Int'l. J. Heat & Mass Transfer
113. "Motion of a Spherical Particle in a Turbulent Flow," by P.K. Khosla and S. Lederman	PIBAL Report No. 73-22, 1973
114. "The Chord-Wise Pressure Distribution on a Rotating Axial-Flow Compressor Blade," by H. L. Moses and W.F. O'Brien	Proceedings, 2nd International Symposium on Air Breathing Engines, 1974
115. "A Multichannel Telemetry System for Flow Research on Turbomachine Rotors," by W. O'Brien and H. Moses and H.R. Carter	ASME Paper No. 74-GT-112, 1974
116. "On-Rotor Studies of Rotating Stall," by W. O'Brien and H. Moses	Project SQUID Workshop on Unsteady Flows in Jet Engines, 1974
117. "Relaxation Rates from Time-of-Flight Analysis of Molecular Beams," by R.J. Gallagher and J.B. Fenn	J. Chem. Phys. 60, 1974
118. "Rotational Relaxation in Molecular Hydrogen," by R. J. Gallagher and J. B. Fenn	J. Chem. Phys. 60, 1974

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119.	"Rotational Relaxation in Molecular Nitrogen," by R.J. Gallagher and J.B. Fenn	Proceedings of the 9th Symposium on Rarefied Gas Dynamics, 1974
120.	"Clustering of Water on Hydrated Protons in a Supersonic Free Jet Expansion," by J.Q. Searcy and J.B. Fenn	J. Chem. Phys.
121.	"Analysis of Unsteady Transonic Channel Flow with Shock Waves," by G.K. Richey and T.C. Adamson, Jr.	AIAA Paper No. 75-61 (1975)
122.	"On the Flow Near a Weak Shock Wave Downstream of a Nozzle Throat," by A.F. Messiter and T.C. Adamson, Jr.	J. Fluid Mech., 69, 1975
123.	"Asymptotic Solutions for Nonsteady Transonic Channel Flows," by A.F. Messiter and T.C. Adamson, Jr.	Symposium Transsonicum II, Gottingen, Germany, Sept. 1975
124.	"Unsteady Radial Transonic Flow with Shock Waves," by M. Sichel	Fluid Dynamics Transactions, 7 1975
125.	"The Effect of Strain Rate on Diffusion Flames," by G.F. Carrier, F.E. Fendell and F.E. Marble	SIAM J. Appl. Math, 28, March 1975
126.	"Vortex Pairing: The Mechanism of Turbulent Mixing Layer Growth at Moderate Reynolds Number," by C.D. Winant and F.K. Browand	JFM, 63, 1974
127.	"Analysis of a Simple Circuit for Constant Temperature Anemometry," by P.D. Weidman and F.K. Browand	J. Physics, 8, 1975
128.	"Elementary Combustion Reaction Kinetic Measurements at Realistic Temperatures," by A. Fontijn	AeroChem TA-112, May 1975
129.	"Raman Scattering Studies of Combustion," by M. Lapp and D.L. Hartley	Combustion Science and Technology and SQUID Workshop on Combustion Measurements in Jet Propulsion Systems (1975)
130.	"The Role of Physics in Combustion" in *Efficient Use of Energy*, edited by D.L. Hartley, D.R. Hardesty, M. Lapp and F. Dryer	American Institute of Physics Conference Proceedings No. 25 (1975)

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132. "Raman Band Contours for Water Vapor as a Function of Temperature," by J. Bribes, R. Gaufres, M. Monan, M. Lapp and C.M. Penney	GE Report No. 75CRD170 (1975)
133. "Threshold Excitations, Relaxation Oscillations and Effect of Noise in an Enzyme Reaction," by H.S. Hahn, A. Nitzan, P. Ortoleva and J. Ross	Proc. Nat. Acad. Sci., 71 (1974)
134. "On the Theory of Time Resolved Near-Resonance Light Scattering," by H. Metiu, A. Nitzan and John Ross	J. Chem. Phys., 63 (1975)
135. "Theory of Propagation of Discontinuities in Kinetic Systems with Multiple Time Scales: Fronts and Pulses," by J. Ross and P. Ortoleva	J. Chem. Phys. 1975
136. "A Stochastic Theory of Cluster Growth in Homogeneous Nucleation," by K. Kitahara, H. Metiu and J. Ross	J. Chem. Phys 1975
137. "Signature Analysis of Aerodynamic Flutter in a Rotating Blade," by J.W. Daws and W.F. O'Brien	Conference on "Application of Signature Analysis Techniques to Machine Reliability and Performance," N.E. College Aug. 1975
138. "An On-Rotor Investigation of Rotating Stall in an Axial-Flow Compressor Stage," by W.F. O'Brien, H.L. Moses and M.R. Sexton	Propulsion and Energetics Panel (AGARD) Sept. 1975
139. "Unsteady Effects on a Low Pressure Extinction Limit of Solid Propellants," by B.R. Baliga and J.S. T'ien	AIAA Paper No. 75-229 (1975)
140. "A Discussion on the Extinction Condition of a Diffusion Flame," by J.S. T'ien	J. Fire and Flammability, 6 1975

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141.	"Flammability Study of Polymer Fuels using Counter-Flow Diffusion Flame Technique," by S. Singhal and J.S. T'ien	CWS Meeting of the Combustion Institute, April 1975
142.	"Turbulent Mixing in a Two-Dimensional Jet," by M.S. Uberoi and P.I. Singh	Physics of Fluids, 18, 1975
143.	"Experiments on Turbulent Structure and Heat Transfer in a Two-Dimensional Jet," by J. Bashir and M.S. Uberoi	Physics of Fluids, 18, 1975
144.	"Swirling Shallow Submerged Turbulent Plumes," by J.P. Narain	ASME Paper 74-WA-APM-22, 1975
145.	"Three Dimensional Turbulent Wall Jet," by J.P. Narain	The Canadian Journal of Chemical Engineering, 53, 1975
146.	"Some Observations on Condensation in Free Jets," by R.J. Gallagher, R.T.V. Kung and J.B. Fenn	5th International Symposium on Molecular Beams, Nice, April 1975
147.	"Scattering of an Argon Beam by a Liquid Glycerine Surface," by M.P. Sinha and J.B. Fenn	5th International Symposium on Molecular Beams, Nice, April 1975
148.	"On Aerodynamic Separation Methods," by R. Campargue, J.B. Anderson, J.B. Fenn, B.B. Hamel, E.P. Muntz and J.R. White	Proceedings of the 1st European Nuclear Conference, Paris 1975
149.	"Elementary Combustion Reaction Kinetics Measurements over Large Temperature Ranges. The HTFER Technique," by A. Fontijn	AIAA Paper 76-131, January 1976
150.	"Elementary Combustion Reaction Kinetic Measurements at Realistic Temperatures," by A. Fontijn	Combustion Measurements in Modern Techniques and Instrumentation. R. Goulard, Ed. (Hemisphere Book Co., Washington, D.C. 1976)
151.	"Concentration Measurement by Fluorescence," by A. Fontijn	Ibid.
152.	"On Turbulent Flows with Fast Chemical Reactions. Part III: Two-Dimensional Mixing with Highly Dilute Reactants," by P.A. Libby	Combustion Science and Technology, 13, 1976
153.	"Diffusion of Heat Downstream of a Turbulence Grid," by P.A. Libby	Astronautica Acta 2, 1975

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154.	"Remarks on a Kinetic-Theory Approach to Turbulent Chemically Reacting Flows," by P.A. Libby and R.A. Stanford	Combustion Science and Technology, 13, 1976
155.	"An Experimental Investigation of Mixing in Two Dimensional Shear Flows with Applications to Diffusion-Limited Chemical Reactions," by John H. Konrad	Ph.D. Thesis, California Institute of Technology, 1976
156.	"Unsteady Effects on the Low Pressure Limit of Solid Propellants," by B.R. Baliga and J.S. T'ien	AIAA J., Vol. 13, 1975
157.	"A Discussion of the Extinction Condition of a Diffusion Flame," by J.S. T'ien	J. of Fire and Flammability, Vol. 6 1975
158.	"Swirling Shallow Submerged Turbulent Plumes," by J.P. Narain	J. of Hydraulics Division, ASCE Vol. 100, 1974
159.	"Stabilization of Turbulent Axisymmetric Rotating Flows," by J.P. Narain	ASME paper 74-WA-APM-22, 1974
160.	"Turbulent Mixing in a Two-Dimensional Jet," by M.S. Uberoi and P.I. Singh	The Physics of Fluids, Vol. 18, 1975
161.	"Three-Dimensional Turbulent Wall Jet," by J.P. Narain	The Canadian Journal of Chemical Engineering, Vol. 53, 1975
162.	"Measurement Accuracy of Flow Velocity Via a Digital-Frequency-Counter Laser Velocimeter Processor," by J.C.F. Wang	Proceedings of the LDA-Symposium (Copenhagen, 1975)
163.	"Laser Velocimeter Turbulence Spectra Measurements," by J.C.F. Wang	Proceedings of the Minnesota Short Course and Symposium on Laser Anemometry (Minnesota, 1975)
164.	"Velocity Measurement of High-Temperature and High-Speed Subsonic Jet Flows Using Laser Velocimeter," by J.C.F. Wang	Presented at the AGARD/ISL Workshop on Laser Velocimetry at the French-German Research Institute, St. Louis, France (May 1976); also General Electric Report 76CRD136, 1976

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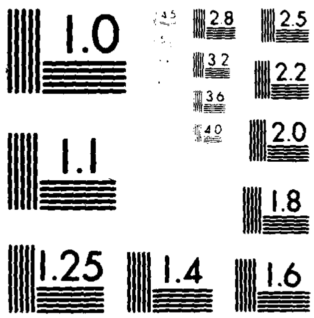

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165. "Physics in Combustion Research," by D. Hartley, M. Lapp and D. Hardesty	Physics Today 28, 1975
166. "Raman Band Contours for Water Vapor as a Function of Temperature," by J.L. Bribes, R. Gaufres, M. Monan, M. Lapp and C.M. Penney	Appl. Phys. Lett. 28, 1976
167. "Raman-Scattering Cross Sections for Water Vapor," by C.M. Penney and M. Lapp	J. Opt. Soc. Am. 66, 1976
168. "Optical Diagnostics of Combustion Processes," in Optical Methods in Energy Conversion, by M. Lapp, ed. by M. Lubin	Proceedings of the Society of Photo-Optical Instrumentation Engineers, Vol. 61, 1975
169. "Raman Scattering Studies of Combustion," by M. Lapp and D.L. Hartley	Combustion, Comb. Sci. Tech. 13, 1976; also in Combustion Measurements Modern Techniques and Instrumentation, ed. R. Goulard (1976)
170. "Concentration Enhancement in Laser Induced Mass Separation," by J. Kline and J. Ross	J. Chem. Phys. 63, 1975
171. "Derivation of Stochastic Equations for Nonequilibrium Ising Mean Field Model," by K. Kitahara, H. Metiu and J. Ross	J. Chem. Phys. 63, 1975
172. "Symmetry Rules for Nonconcerted Reactions," by H. Metiu, T. George and J. Ross	Chem. Phys. 11, 1975
173. "Stochastic Theory of the Kinetics of Phrase Transitions," by H. Metiu, K. Kitahara and J. Ross	J. Chem. Phys. 64, 1976
174. "Molecular Beam Studies of Methyl Radical Reactions with Halogen Molecules: Product Angular and Velocity Distributions," by J. Makowski, C. Mims, G.W. Stewart and J. Ross	J. Chem. Phys. 64, 1976
175. "Photodissociation of NO_2 in the Region 458 to 630 nm," by C.L. Creel and J. Ross	J. Chem. Phys. 64, 1976
176. "A Derivation and Comparison of Two Equations (Landau-Ginzburg and Cahn) for the Kinetics of Phase Traditions," by H. Metiu, K. Kitahara and J. Ross	J. Chem. Phys 65, 1976

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177.	"Nonequilibrium Kinetics: Exact and Approximate Solutions," by S. Hudson and J. Ross	J. Stat. Phys. 14, 1976
178.	"Formation of Temporal and Spatial Structures Through Chemical Instabilities," by J. Ross	Berichte der Bunsen-Gesellschaft, 1976
179.	"Modern Diagnostics of Combustion," by S. Lederman	AIAA Paper No. 76-26
180.	"Some Applications of Laser Diagnostics to Fluid Dynamics," by S. Lederman	AIAA Paper No. 76-21
181.	"An On-Rotor Investigation of Rotating Stall in an Axial-Flow Compressor," by M.R. Sexton, W.F. O'Brien and H.L. Moses	In Unsteady Flow in Turbomachinery AGARD Conf. Proc. No. 177, Monterey, Cal. Sept. 1975
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183.	"The Lift Response of a Rotating Blade of an Axial-Flow Compressor to Inlet Flow Distortion," by T.E. Neal	M.S. Thesis, Mech. Engr. Dept. Va. Poly, Inst. and State Univ., 1975
184.	"The Design and Operation of the VPI&SU High-Speed Turbomachinery Facility," by R.R. Jones	M.S. Thesis, Mech. Engr. Dept. Va. Poly. Inst. and State Univ., 1975
185.	"Clustering of Water on Hydrated Protons in a Supersonic Free Jet Expansion," by J.Q. Searcy and J.B. Fenn	J. Chem. Phys. 61, 1974
186.	"A Kinetic Model for Clustering of Water on Hydrated Protons in a Supersonic Free Jet Expansion," by J.Q. Searcy	J. Chem. Phys. 63, 1975
187.	"Scattering of Argon by a Liquid Glycerine Surface," by M.P. Sinha and J.B. Fenn	Proc. 5th Int. Symp. on Molecular Beams, Nice, 1975
188.	"Interaction Effects in Turbulent Premixed Flames," by K.N.C. Bray and P.A. Libby	Phys. of Fluids, 19, 1976
189.	"Structure of Turbulent Shear Flows: A New Look," by A. Roshko	AIAA Journal 14, 1976; Dryden Research Lecture

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190. "The Mixing Layer at High Reynolds Number: Large-Structure Dynamics and Entrainment," by P.E. Dimotakis and G.L. Brown	JFM 78, 1976
191. "Detailed Study of the Q-Branch Profile of the ν_1 of Water Molecule from 293 K to 1400 K," by J.L. Bribes, R. Gaufres, M. Monan, M. Lapp and C.M. Penney	Proceedings of the Fifth International Conference on Raman Spectroscopy, Universitat Freiburg, 1976, ed. by E.D. Schmid et al. (Hans Ferdinand Schulz Verlag, Freiburg im Breisgau, 1976)
192. "Superradiance and Energy Transfer Within a System of Atoms," by P. Stone, A. Nitzan and John Ross	Physica 84A, 1 (1976)
193. "Dynamical Theory of Migration of an Absorbed Atom on Solid Surfaces," by C.L. Creel and John Ross	J. Chem. Phys. 65, 1976
194. "Experimental Techniques Applicable to Turbulent Flows,"	Pres. at the AIAA 15th Aerospace Sciences Meeting in Los Angeles, Cal., Jan. 1977, AIAA Paper No. 77-213
195. "Experimentally Determined Stability Parameters of a Subsonic Cascade Oscillating Near Stall," by F.O. Carta, and A.O. St. Hilaire	ASME Paper No. 77-GT-47, March 1977
196. "Effects of Laser Modulated Particulate Incandescence on Laser Raman Scattering Diagnostics," by A.C. Eckbreth	J. Applied Physics, October 1977
197. "Variable Density Effects in Turbulent Premixed Flames," by P.A. Libby and K.N.C. Bray	AIAA J. 15, 1186-1193, 1977
198. "Structure of a Turbulent Swirl," by M.S. Uberoi	The Physics of Fluids, Vol 20, No. 5, May 1977.
199. "Transonic Channel Flow with Strong Incoming Shear," by T.C. Adamson, Jr. and M. Sichel	Presented at the XIIIth Biennial Fluid Dynamics Symposium, Advanced Problems and Methods in Fluid Mechanics, Sept. 1977, Olsztyn, Poland
200. "On the Quasiadiabatic Description of the Dynamics of Electronically Adiabatic Chemical Reactions," by Mukamel, Shaul and John Ross	J. Chem. Phys. 66, 3749, 1977

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201. "Formation of Ensembles with Constraints and Coherence," by Procaccia, Itamar, Shaul,Mukamel, and John Ross.	J. Chem. Phys. 66, 5064, 1977
202. "Comment on Non-Statistical Behavior in Laser Chemistry and Chemical Activation," by Mukamel, Shaul and John Ross	J. Chem. Phys. 66, 5235, 1977
203. "Aperiodic and Periodic Oscillations in Fluorescence Intensity from Irradiated Chlorocarbon Solutions of Anthracene and 9, 10-Dimethylanthracene," by Robert L. Bose, John Ross and Mark S. Wrighton	J. Am. Chem. Soc. 99, 1977
204. "Raman Measurements on Flames," by M. Lapp and C.M. Penney	Advances in Infrared and Raman Spectroscopy, Vol. 3, Ed. by Clark, R.J.H. and R.E. Hester. Heyden and Son Ltd., London, Chapt 6.
205. "Measurements on Turbulent Hydrogen Flames in a Circular Air Duct," J.C.F Wang and B.W. Gerhold	AIAA Paper No. 77-48, 1977
206. "Franck-Condon Factors in Studies of Dynamics of Chemical Reactions. I. General Theory, Application to Collinear Atom-Diatom Reactions," by George C. Schatz and John Ross	J. Chem. Phys. 66, 1021, 1977
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209. "On Stochastic Reductions in Molecular Collision Theory: Projection Operator Formalism; Application to Classical and Quantum Forced Oscillator Model," by George C. Schatz, Frank J. McLafferty and John Ross	J. Chem. Phys. 66, 3609, 1977
210. "Cooperative Instability Phenomena in Arrays of Catalytic Sites," by Bimpong-Bota, E.K., A. Nitzan, P. Ortoleva and John Ross.	J. Chem. Phys. 66, 3640, 1977

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211. "Coherent and Diffusional Motion of a Chemisorbed Atom," H. Metiu, K. Kitahara, R. Silbey and John Ross.	Chem. Phys. Letters 43, 189 1976
212. "Temporal and Spatial Structures in Chemical Instabilities," John Ross	Ber. Bunsenges, 80, 1112 (1976)
213. "Some Applications of Laser Diagnostics to Fluid Dynamics," by S. Lederman	Pres. at the AIAA 14 Aerospace Sciences Mtg., Washington D.C. Jan., 1976, AIAA Paper No. 76-21
214. "Modern Diagnostics of Combustion," by S. Lederman	Pres. at the AIAA 14th Aerospace Sciences Mtg., Washington, D.C., Jan. 1976, AIAA Paper No. 76-26; Published in Experimental Diagnostics in Gas Phase Combustion Systems, Vol. 53, Ed. Ben T. Zinn
215. "Experimental Investigation of Coaxial Turbulent Jets," by S. Lederman	Collection of Technical Papers of the 18th Israel Annual Conference on Aviation and Astronautics, Weizman Science Press, May, 1976
216. "HTFER Kinetics Studies of $Al + CO_2 \rightarrow AlO + CO$ from 300 to 1900 K, A Non-Arrhenius Reaction," by A. Fontijn and W. Felder	J. Chem. Phys. 67, 1561 (1977)
217. "Aspects of Turbulent Combustion," by A.K. Varma, E.S. Fishburne and C. duP. Donaldson	AIAA 15th Aerospace Sciences Meeting, AIAA Paper No. 77-100, Jan. 1977.
218. "Investigations of Chemical Reactions in a Turbulent Media," by E.S. Fishburne and A.K. Varma	Presented at the Sixth International Colloquium on Gasdynamics of Explosions and Reactive Systems, Stockholm, Sweden, August, 1977
219. "The V.P.I. Gas Turbine and Turbomachinery Research Laboratory," by W.F. O'Brien, H.L. Moses, R.R. Jones and J.F. Sparks	ASME Paper No. 77-GT-73, March 1977
220. "Blade Pressure Distributions During Surge of an Axial-Flow Compressor," by C. Jones	M.S. Thesis, VPI&SU, August, 1977
221. "An Experimental Study of Rotating Stall in an Axial-Flow Compressor," by G. Verdesoto	M.S. Thesis, VPI&SU, Sept. 1977

No.	Title and Author	Other Presentations
222.	"Performance and Stalling Behavior of an Axial-Flow Compressor Subjected to Three Circumferential Distortion Levels," by W. Gauden	M.S. Thesis, VPI&SU, Sept. 1977
223.	"Simultaneous Solution of the Boundary Layer and Free Stream with Separated Flow," by H.L. Moses, R.R. Jones, W.F. O'Brien and R.S. Peterson	AIAA J., V 16, No. 1, Jan. 1978
224.	"The Study of Flames by Raman Spectroscopy," by M. Lapp	Proceedings of the Sixth International Conference on Raman Spectroscopy, Vol 1, ed. by E.D. Schmid, R.S. Krishnan, W. Kiefer and H.W. Shrotter (Heyden and Son Ltd., London, 1978)
225.	"Measurements in Highly Turbulent Flows: Steady and Unsteady Separated Turbulent Boundary Layers," by R.L. Simpson and Y.-T. Chew	Invited Paper, Third International Workshop on Laser Velocimetry, July, 1978
226.	"CARS Investigations in Flames," by A.C. Eckbreth	Paper presented at the XVIIth Symposium (International) on Combustion, Leeds, England, August, 1978
227.	"Combustion Diagnostics by Coherent Anti-Stokes Raman Spectroscopy," by R.J. Hall and A.C. Eckbreth	Paper presented at the SPIE 22nd International Technical Symposium and Instrument Display, August, 1978, San Diego, CA
228.	"CARS Diagnostic Investigations of Flames," by A.C. Eckbreth and R. J. Hall	Invited paper presented at the NBS 10th Materials Research Symposium on Characterization of High Temperature Vapors and Gases, Sept. 1978, Gaithersburg, MD
229.	"Unsteady Transonic Flows with Shock Waves in an Asymmetric Channel," by John S.-K. Chan and T.C. Adamson, Jr.	AIAA Journal, Vol. 16, April 1978
230.	"An Experimental Study of Large-Scale Structure Interactions in a Two-Dimensional Turbulent Mixing Layer," by B.O. Latigo and F.K. Browand	Bulletin of the American Physical Society, Nov. 1978, (abstract of paper presentation, APS Division of Fluid Dynamics, Los Angeles, CA)

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231.	"Cascade Performance of a Double Arc Compressor Blade at Low Reynolds Number," by Keller and J. Urs	M.S. Thesis, VPI&SU, Oct. 1978
232.	"The Use of Laser Raman Diagnostics in Flow Fields and Combustion," by S. Lederman	Published in Prog. Energy Combust. Sci., 3, 1977
233.	"The Application of Laser Scattering to Flow Field Diagnostics," by S. Lederman	Proc. of Second Bat-Sheva Seminar on MHD-flows and Turbulence held at the Ben-Gurion University of the Negev, March, 1978, Beer-Sheva, Israel
234.	"An Experiment on Spontaneous Flame Oscillation Prior to Extinction," by W.Y. Chan and J.S. T'ien	AIAA Paper No. 77-184
235.	"Stochastic Reduction for Dynamics of Reactions with Complex Formation," by D.J. Zvijac, S. Mukamel and John Ross	J. Chem. Phys. 67 2007 (1977)
236.	"The 1977 Nobel Prize in Chemistry," by I. Procaccia and John Ross	Science 198, 716 (1977)
237.	"Stability and Relative Stability in Reactive Systems Far from Equilibrium. I. Thermodynamic Analysis," by I. Procaccia and John Ross	J. Chem. Phys. 67, 5558 (1977)
238.	"Stability and Relative Stability in Reactive Systems Far from Equilibrium. II. Kinetic Analysis of Relative Stability of Multiple Stationary States," by I. Procaccia and John Ross	J. Chem. Phys. 67, 5565 (1977)
239.	"Investigations of Chemical Reactions in a Turbulent Media," by Ashkok K. Varma	Paper presented at the 6th Int'l Colloquium on Gasdynamics of Explosions and Reactive Systems, Stockholm, Sweden, Aug. 1977
239/1	"A Shock Tube Study of the Recombination of Carbon Monoxide and Oxygen Atoms," by A. M. Dean	J. Chem. Phys., 66, 598 (1977)
240.	"Large Scales in the Developing Mixing Layer," by F.K. Browand and P.D. Weidman	J. Fluid Mech., 76 , 1976

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241.	"Three Dimensional Transonic Flow in Channels," by M. Sichel and T.C. Adamson, Jr.	Presented at 13th Biennial Fluid Dynamics Syjposium, Sept. 1977, Olsztyn, Poland
242.	"Kinetics of Aerosol Formation in Irradiated Gaseous NO_2-SO_2 Mixtures," by K. Iwamoto, N. Presser and J. Ross	J. Chem. Phys. 68, 663 (1978)
243.	"Consequences of Size Dependence of Transition Probabilities in Stochastic Equations," by S. Mukamel, I. Procaccia and J. Ross	J. Chem. Phys. 68, 1205 (1978)
244.	"Modeling of Scalar Correlations in Turbulent Mixing and Reacting Flows," by Ashok K. Varma	Paper presented at the 1978 Int'l Conference on Physicochemical Hydrodynamics (the Levich Conf.), Wash.D.C. Nov. 1978
245.	"Modeling of Scalar Probability Density Functions in Turbulent Mixing and Reacting Flows," by Ashok K. Varma	Paper presented at the 71st Meeting of the American Institute of Chemical Engineers, Miami, FL, Nov. 1978
246.	"Secondary Structures in Mixing Layers," by L. Bernal and A. Roshko	Presented at the 31st Reg. Meeting of the Division of Fluid Dynamics American Physical Society, Nov. 1978; Bulletin of the American Physical Society 23, 1978
247.	"Averaging Considerations for Pulsed, Laser Raman Signals from Turbulent Combustion Media," by A.C. Eckbreth	Combust. Flame, Vol. 31, 1978
248.	"A Shock Tube Study of the $H_2/O_2/CO/Ar$ and $H_2/N_2O/CO/Ar$ Systems," by A. M. Dean	Combust. and Flame, 32, 73 (1978)
249.	"Experimentally Determined Stability Parameters of a Subsonic Cascade Oscillating Near Stall." by F.O. Carta and A.O. St. Hilaire	Transactions, ASME, Journ. of Engineering for Power, Vol. 100, No. 1, Jan. 1978
250.	"Chemical Relaxation Pulses and Waves. Analysis of Lowest Order Multiple Time Scale Expansion," by M. Collins and J. Ross	J. Chem. Phys. (in press)
251.	"Statistical Reduction for Strongly Driven Simple Quantum Systems," by S. Mukamel, I. Oppenheim and J. Ross	Physical Review (in press)
252.	"On the Theory of Unimolecular Reactions: Application of Mean First Passage time to Reaction Rates," by I. Procaccia, S. Mukamel and J. Ross	J. Chem. Phys. (in press)

Title and Author	Other Presentations
253. "A Basis for Orbital Symmetry Rules," by H. Metiu, G.M. Whitesides and J. Ross	Angew. Chemie (in press)
254. "Statistical Mechanical Theory of the Kinetics of Phase Transitions," by H. Metiu, K. Kitahara and J. Ross	Adv. Stat. Mech. (in press)
255. "Remarks on Chemical Instabilities," by J. Ross	Proceedings of the XVIth Solvay Conf. to appear in Advances in Chemical Physics, Wiley-Interscience, N.Y., (in press)
256. "Instability and Far-from-equilibrium States of Chemically Reacting Systems," by P. Hanusse, P. Ortoleva and J. Ross	Advances in Chemical Physics (in press)
257. "Franck-Condon Factors in Studies of Dynamics of Chemical Reactions. IV. Non-adiabatic Collisions," by D.J. Zvijac and J. Ross	J. Chem. Phys. (in press)
258. "On the Efficiency of Rate Processes," by D. Gutkowicz-Krusin, I. Procaccia and J. Ross	J. Chem. Phys. (submitted)
259. "Analytic Results for Asymmetric Random Walk with Exponential Transition Probabilities," by D. Gutkowicz-Krusin, I. Procaccia and J. Ross	J. Stat. Phys. (submitted)
260. "Comment on 'Rate of Polymorphic Transformation Between Phase II and III of Hexacloroethane'," by H. Metiu and J. Ross	J. Chem. Soc. (submitted)
261. "Kinetic Instabilities in First Order Phase Transitions," by R. Lovett, P. Ortoleva and J. Ross	J. Chem. Phys. (submitted)
262. "Development of Three Dimensionality in Turbulent Mixing Layers," by L.P. Bernal, R.E. Breidenthal, G.L. Brown, J.H. Konrad and A. Roshko.	Proceedings 2nd Symposium on Turbulent Shear Flows, Imperial College, London, July, 1979
263. "Effects of Finite Reaction Rate and Molecular Transport in Premixed Turbulent Combustion," by P.A. Libby, K.N.C. Bray and J.B. Moss	Combust. Flame 34 (1979)
264. "A Non-Gradient Theory for Premixed Turbulent Flames," by P.A. Libby	Mech. Today 5 (accepted)
265. "Preferential Entrainment in a Two-Dimensional Turbulent Jet in a Moving Stream," by P. Anderson, J.C. LaRue and P.A. Libby	Phys. Fluids (accepted)

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266. "Decomposition of n-butane," by S.N. Vaughn, J.F. Merklin and T.W. Lester	J. Chem. Phys. (submitted)
267. "Temperature, Concentration and Velocity in Jets, Flames and Shock Tubes," by S. Lederman, A. Celentano and J. Glaser	Phys. of Fluids, 22, 1065 (1979)
268. "A Wall-Flow-Direction Probe for Use in Separating and Reattaching Flows," by J.K. Eaton, A.H. Jeans, J. Ashjaee and J.P. Johnston	Journal of Fluids Engineering (Trans. ASME) 1979
269. "Measurements in a Reattaching Turbulent Shear Layer," By J.K. Eaton, J.P. Johnston and A.H. Jeans.	Proceedings of the 2nd Symposium on Turbulent Shear Flows, July 1979 Imperial College, London.
270. "Straight-Walled, Two-Dimensional Diffusers -- Transitory Stall and Peak Pressure Recovery," by J. Ashjaee and J.P. Johnston	Presented at the ASME meeting, Dec. 1979, Symposium on 'Flow in Primary, Non-Rotating Passages in Turbomachines'
271. "Response Behavior of Hot-Wires in a Skewed Mean Flow," by F.B. Gessner and M.T. Littlefield	To be submitted to JFM for publication
272. "CARS Investigations in Sooting and Turbulent Flames" by A.C. Eckbreth	Project SQUID Technical Report UTRC-5-PU, March 1979
273. "Investigations of Coherent Anti-Stokes Raman Spectroscopy (CARS) for Combustion Diagnostics," by A.C. Eckbreth, R.J. Hall and J.A. Shirley	AIAA Paper 79-0083, New Orleans, LA. January 1979
274. "CARS Thermometry in a Sooting Flame," by A.C. Eckbreth and R.J. Hall	Combust. Flame, Vol. 36, Sept. 1979
275. "Shock Tube Studies of Formaldehyde Pyrolysis," by A.M. Dean	17th Symposium (International) on Combustion (in press)
276. "Shock Tube Studies of Formaldehyde Oxidation," by A.M. Dean	Combust. and Flame (submitted)
277. "Instantaneous Two-Dimensional Concentration Measurements in a Jet Flow by Mie Scattering," by M.B. Long, B.F. Webber and R.K. Chang	Appl. Phys. Lett. 34, 22 (1979)

Title and Author	Other Presentations
278. "Specie Specific Two-Dimensional Average Concentration Measurements in a Jet Flow by Raman Scattering," by B.F. Webber, M.B. Long and R.K. Chang	Appl. Phys. Lett. (submitted)
279. "Spatially Resolved Coherent anti-Stokes Raman Spectroscopy from a Line across a CH_4 Jet," by D.V. Murphy, M.B. Long and R.K. Chang and A.C. Eckbreth	Opt. Lett., June 1979
280. "Effect of Interblade Phase Angle and Incidence Angle on Cascade Pitching Stability," by F.O. Carta and A.O. St. Hilaire	Presented at the ASME Gas Turbine Conf., San Diego, CA, March 1979, Paper No. 79-GT-153. (To be published in Transactions, ASME Journal of Engineering for Power)
281. "Growth of the Two-Dimensional Mixing Layer from a Turbulent and Nonturbulent Boundary Layer," by F.K. Browand and B.O. Latigo	Physics of Fluids 22, 1979
282. "Large Scale Structure Interactions in a Two-Dimensional Turbulent Mixing Layer," by B.O. Latigo	Ph.D. Thesis presented to the Univ. of Southern California, Jan. 1979
283. "A Visual Investigation of Turbulence in Stagnation Flow about a Circular Cylinder," by W. Sadeh	Forthcoming in Journal of Fluid Mechanics

4. REVIEWS, WORKSHOPS AND COLLOQUIA

Technical reviews on selected subjects of basic research interest in propulsion were funded under Project SQUID. Each review was expected to provide a critical summary of the current state of research in the chosen subject along with a statement of fruitful directions for further research.

A Project SQUID Workshop had the following general objectives.

1) Providing a meeting ground for specialists and persons with definite interest in a selected subject, selected from industry, university institutions and government representatives from in-house laboratories and funding agencies.
2) In-depth discussion of the subject with the aid of invited papers.
3) Determination of useful directions for further research.

The subject for a Workshop was selected on the basis of long-term needs of the Navy in jet propulsion, taking into account the current and future thrust areas of Project SQUID.

Project SQUID Workshops were sponsored by the ONR, in most cases in cooperation with other selected funding agencies.

The Proceedings of Workshops were published as reports and made available for purchase, as all other SQUID - Technical Reports were made available, through the NTIS.

The proceedings have also become available through general publishers in several cases.

A Project SQUID Colloquium was defined as a meeting of carefully-

selected specialists deeply and personally involved in research in the subject of the Colloquium. The principal objective of a Colloquium was an in-depth discussion of the current state of research or development in the selected subject and the determination, by the participating specialists, of specific and precise needs for advances in the subject. The emphasis in a Colloquium was on a carefully-selected narrow technical/ scientific area and on providing a forum for those who were actively engaged in research in the chosen area.

The proceedings of Colloquia have been published and made available by the ONR in various forms to the general public.

4.1. Technical Reviews

4.1.1. Turbulent Mixing

a) Author: S.N.B. Murthy

b) Publication Reference: Turbulent Mixing in Nonreactive and Reactive Flows. Edited by S.N.B. Murthy. Plenum Press: New York, 1975.

4.1.2. Combustion Measurements

a) Author: R. Goulard

b) Publication Reference: Combustion Measurements. Modern Techniques and Instrumentation. Edited by R. Goulard. Hemisphere Publishing Corporation: Washington, 1976.

4.1.3. Gas Turbine Combustor Design Problems

a) Author: Arthur H. Lefebvre

b) Publication Reference: Gas Turbine Combustor Design Problems. Edited by Arthur H. Lefebvre. Hemisphere Publishing Corporation: Washington, 1978.

4.2 Workshops

4.2.1 Gas Turbine Combustor Design Problems

a) Chairman: A.H. Lefebvre, Purdue University, West Lafayette, Indiana.

b) Sponsored by: Air Force Office of Scientific Research, Naval Air Systems Command and Office of Naval Research (Power Program).

c) Date: May 31-June 1, 1978.

d) Place: Purdue University, West Lafayette, Indiana.

e) References to Proceedings:

1. Report No. PU-RI-80: Proceedings of Workshop on Gas Turbine Combustor Design Problems.
   Edited by A.H. Lefebvre, Published for the ONR by School of Mechanical Engineering, Purdue University, West Lafayette, Indiana, 1980. Note that the reference number required for obtaining this document from the NTIS is not available at the date of this Report.
2. Gas Turbine Combustor Design Problems
   Edited by A.H. Lefebvre, Hemisphere Publishing Corporation, Washington D.C., 1980.

f) Contents of Proceedings

Preface: Welcoming Remarks. Introduction. PROBLEMS IN GAS TURBINE COMBUSTORS: Problems and Promises in Gas Turbine Design Development. COMBUSTOR AERODYNAMICS: Performance of the Vortex-controlled Diffuser (VCD) in an Annular Combustor Flowpath. Noise from Gas Turbine Combustors. FUELS AND COMBUSION: Fuel Property Effects on Combustor Performance. Problems due to Multifuel Operation of Gas Turbine Combustors. Residual Fuel Combustion in Industrial Gas Turbines. PATTERN FACTOR AND WALL TEMPERATURE: Pattern Factor Analysis. Gas Turbine Combustor Liner Durability - The Hot Streak Problem. Combustor Cooling - Old Problems and New Approaches. RELIGHTING: Basic Ignition Related to Altitude Relight Problems. EMISSIONS: Gas Turbine Engine Emissions Abatement - Status and Needed Advancements. Combustion of Coal-

derived Liquids and Shale Oil in Gas Turbine Combustors. MODELING: Introduction to Sections on Modeling, Diagnostics, and Measurement. Three-dimensional Two-Phase Mathematical Modelling of Gas Turbine Combustors. Coalescence/Dispersion Modeling of Gas Turbine Combustors. DIAGNOSTICS AND MEASUREMENTS: Spray Diagnostics. Spatially Precise Laser Diagnostics for Practical Combustor Probing. PANEL DISCUSSION: Panel Discussion. SUMMARY: Summary and Observations. Workshop Participants.

4.2 Workshops

4.2.2 Alternative Hydrocarbon Fuels: Combustion and Chemical Kinetics

a) Chairmen: Craig T. Bowman, Stanford University, Stanford, California, and Jorgen Birkeland, Department of Energy, Washington, D.C.

b) Sponsored by: Department of Energy, Air Force of Scientific Research, Naval Air Systems Command, Office of Naval Research.

c) Date: September 7-9, 1977.

d) Place: Loyola College Conference Center, Columbia, Md.

e) References to Proceedings:

1. Report No. PU-R2-78. Proceedings of Workshop on Alternative Hydrocarbon Fuels: Combustion and Chemical Kinetics.
   Edited by Craig T. Bowman and Jorgen Birkeland. Published for the ONR by School of Mechanical Engineering, Purdue University, West Lafayette, Indiana, 1978. Reference No. AD 061 050.
2. Alternative Hydrocarbon Fuels: Combustion and Chemical Kinetics.
   Edited by Craig T. Bowman and Jorgen Birkeland, American Institute of Aeronautics and Astronautics, New York, 1978.

f) Contents of Proceedings

Preface. INTRODUCTION. ALTERNATIVE FUEL AVAILABILITY AND ANTICIPATED COMBUSTION PROBLEMS. Alternative fuels and Combustion Problems. Future Fuels in Gas Turbine Engines. Alternative Fuels for Reciprocating Internal Combustion Engines. Use of Alternative Fuels in Stationary Combustors. CRITICAL PROCESSES IN COMBUSTION OF ALTERNATIVE FUELS. Ignition/Stabilization/Atomization: Alternative Fuels in Gas Turbine Combustors. Combustion and Chemical Kinetics Problems in Internal Combustion Engines. Combustion of Droplets and Sprays of Some Alternative Fuels. Flame Emissivities: Alternative Fuels. PYROLYSIS AND OXIDATION

KINETICS OF ALTERNATIVE FUELS. Pyrolysis and Oxidation of Aromatic Compounds. Combustion Chemistry of Chain Hydrocarbons. Liquid-Phase Reactions of Vaporizing. Hydrocarbon Fuels. POLLUTANT EMISSIONS CONSIDERATIONS FOR ALTERNATIVE FUEL COMBUSTION. Role of Aromatics in Soot Formation. Kinetics of Nitric Oxide Formation in Combustion. Emission Control Techniques for Alternative Fuel Combustion. SUMMARY AND CONCLUSIONS. Panel Discussion: Alternative Fuels Policy. Panel Discussion: Alternative Fuels Technology. Index to Contributors to Volume 62.

4.2.3. Cooling Problems in Aircraft Gas Turbines

a) Chairman: A.D. Wood, ONR Branch Office, Boston, Mass.

b) Sponsored by: Naval Air Systems Command, Office of Naval Research.

c) Date: September 27-28, 1978.

d) Place: Naval Post Graduate School, Monterrey, Calif.

e) Reference to Proceedings:

1. A summary report on the Workshop submitted by A.D. Wood.

4.2.4 Engine-Airframe Integration

a) Chairman: S.N.B. Murthy, Purdue University, West Lafayette, Indiana.

b) Sponsored by: Air Force Office of Scientific Research, Naval Air Systems Command, Office of Naval Research.

c) Date: May 11-12, 1977.

d) Place: Naval Academy, Annapolis, Maryland.

e) References to Proceedings;

1. Report No. PU-RI-78. Proceedings of Workshop on Engine-Airframe Integration.
   Edited by S.N.B. Murthy. Published for the ONR by School of Mechanical Engineering, Purdue University, West Lafayette, Indiana, 1978. Reference No.

f) Contents of Proceedings

Preface. Welcoming Remarks. V/STOL Aircraft Design Consideration. From the AMST to the Future. Propulsion Technology needs for V/STOL Aircraft. Engine-Airframe Integration, Current Practices and Future Requirements for Army Aircraft. Engine Cycle Considerations and Associated Installation Problems for Short Haul Aircraft. The Shaft Coupled Lift/Cruise Fan Propulsion System for V/STOL Aircraft. Flight/Propulsion Control Systems for 1990 Applications. Propulsion Research Requirements for Powered Lift Aircraft. Computational Methods in Predicting Airframe Propulsion System Interaction. Effects of Over-The-Wing Pylon-Mounted Engines on Transport Airplane Performance. Upper Surface Blowing Aerodynamic and Acoustic Characteristics. Thrust Augmentation and Noise Attenuation of Ejector Shrouds. Compatibility Technology Requirements. Propulsion Induced Effects for VTOL Aircraft in Ground Effect. The Airjet Distortion Generator System: A New Tool for Aircraft Turbine Engine Testing. General Discussion. Summary and Recommendations.

4.2.5 Turbulence in Internal Flows

a) Chairman: S.N.B. Murthy, Purdue University, West Lafayette, Indiana.

b) Sponsored by: Naval Air Systems Command and the Office of Naval Research (Fluid Dynanics Program and Power Program)

c) Date: June 14-15, 1976.

d) Place: Airlie House, Warrenton, Virginia.

e) References to Proceedings:

1. Report No. PU-RI-77. Proceedings of Workshop on Turbulence in Internal Flows.
Edited by S.N.B. Murthy. Published for the ONR by School of Mechanical Engineering, Purdue University, West Lafayette, Indiana, 1976. Reference No. AD A040966.

2. Turbulence in Internal Flows.
Edited by S.N.B. Murthy, Hemisphere Publishing Corporation, Washington, D.C., 1976.

f) Contents of Proceedings:

Preface. Thirty years of Research. Welcoming Remarks. Introduction. Preliminary Report on Sheared Cellular Motion as a Qualitative Model of Homogeneous Turbulent Shear Flow. Interacting Shear Layers in Turbomachines and Diffusers. Some Preliminary Observations on the Effect of Initial Conditions on the Structure of the Two-Dimensional Turbulent Mixing Layer. On the Developing Region of a Plane Mixing Layer. The Effects of an External Turbulent Uniform Shear Flow on a Turbulent Boundary Layer. The Effect of Swirl on the Turbulence Structure of Jets. Implications of the Structure of the Viscous Wall Layer. Further Investigation of the Linear and Nonlinear Theory for Constant-Temperature Hot-Wire Anemometers. Results of a Two Equation Model for Turbulent Flows and Development of a Relaxation Stress Model for Application to Straining and Rotating Flows. Application of the

Turbulence-Model Transition-Prediction Method to Flight-Test Vehicles. A Second Moment Turbulence Model Applied to Fully Separated Flows. The Modelling of a Turbulent Near Wake Using the Interactive Hypothesis. Some Important Physical Phenomena in Flows with Separated Turbulent Boundary Layers. Turbulence Velocity Scales for Swirling Flows. Effect of Freestream Turbulence and Initial Boundary Layers on the Development of Turbulent Mixing Layers. Measurements in Curved Flows. Small Disturbances in a Compressor with Strong Swirl. Wake Cutting Experiments. Some Turbulence and Unsteadiness Effects in Turbomachinery. Visual Study of Oscillating Flow over a Stationary Airfoil. Generation, Measurement and Suppression of Large Scale Vorticity in Internal Flows. Panel Discussion. Summary Report. Index.

4.2.6 *Transonic Flow Problems in Turbomachinery*

a) Chairmen: T.C. Adamson, Jr., Department of Aerospace Engineering, The University of Michigan, and M.F. Platzer, Department of Aeronautics, Naval Postgraduate School, Monterery, California.

b) Sponsored by: Office of Naval Research (Project SQUID), the Naval Air Systems Command, and the Air Force Office of Scientific Research.

c) Date: February 11-12, 1976.

d) Place: Naval Postgraduate School, Monterey, California.

e) References to Proceedings:

1. Report No. MICH-16-PU: Proceedings of Workshop on Transonic Flow Problems in Turbomachinery.
   Edited by T.C. Adamson, Jr. and M.F. Platzer, Published for the ONR by School of Mechanical Engineering, Purdue University, West Lafayette, 1976. Reference No. A 037 060.
2. Transonic Flow Problems in Turbomachinery
   Edited by T.C. Adamson, Jr. and M.F. Platzer, Hemisphere Publishing Corporation, Washington, D.C., 1976.

f) Contents of Proceedings

Preface. Thirty Years of Research. Welcoming Remarks. Analysis: Basic Formuation for Transonic Flow Problems in Rotors. Introductory Remarks for Session on Basic Formuation for Transonic Flow Problems in Rotors. Basic Formulation for Transonic Flow Problems in Rotors. Three-Dimensional Inviscid Flow Through a Highly-Loaded Transonic Compressor Rotor. Calculation of 3-Dimensional Choking Mass Flow in Turbomachinery with 2-Dimensional Flow Models. Three Dimensional Transonic Shear Flow in a Channel. Some Formulation Considerations in 3-D Transonic Flow Computation. Computation of Steady and Periodic Two-Dimensional Nonlinear Transonic Flows in Fan and Compressor Stages. Analysis: Computational Methods. Computation of

Transonic Potential Flows in Turbomachinery. Finite Difference Procedure for Unsteady Transonic Flows: A Review. Four Issues in the Computation of Transonic Flows in Turbomachinery. Comparison of a Finite Difference Method with a Time-Marching Method for Blade to Blade Transonic Flow Calculations. Rotational Transonic Internal Flows. Application of a Multi-Level Grid Method to Transonic Flow Calculations. Application of Time-Dependent Finite Volume Method to Transonic Flow in Large Turbines. Finite-Difference Calculations of Three-Dimensional Transonic Flow Through a Compressor Blade Row, Using the Small-Disturbance Nonlinear Potential Equation. Transonic Relaxation Methods. Calculation of Transonic Potential Flowfields About Complex, Three-Dimensional Configurations. Calculation of Supercritical Flow Past a Double Wedge by Telenin's Method. Supercritical Cascade Design. A Navier-Stokes Solution of the Three-Dimensional Viscous Compressible Flow in a Centrifugal Compressor Impeller. Shock-Fitting in Transonic Flow Computation. Efficiency Gains of Second Order Accurate Methods with Shock Fitting. Solutions to Internal Transonic Flows via Parametric Differentiation. Perturbation Solutions for Blade-to-Blade Surfaces of a Transonic Compressor. Viscous Effects in Transonic Flows. On the Prediction of Viscous Phenomena in Transonic Flows. Normal Shock Wave-Turbulent Boundary Layer Interactions in Transonic Flow Near Separation. Interactions of Normal Shock Waves with Turbulent Boundary Layers at Transonic Speeds. Coupled Inviscid/Boundary-Layer Flow Field Predictions for Transonic Turbomachinery Cascades. Experiment. Review of Experimental Work on Transonic Flow in Turbomachinery. Flow in a Transonic Compressor Rotor. Comparison of Prediction of Transonic Flow in a Fan with Flow Measurements Taken Using a Laser Doppler Velocimeter. Nonintrusive Measurements of the Flow Vectors Within the Blade Passages of a Transonic Compressor Rotor. A Transonic/Supersonic Smoke Tunnel for the Investigation of Cascade Loss Models. A Laser Velocimeter

System for Small Radial Turbomachinery. Laser Doppler Velocimeter Measurements in a Two-Dimensional Transonic Flow. Real Time Measurements in a Transonic Compressor. A Comparative Evaluation of Numerical and Experimental Cascade Data. The Effect of Leading-Edge Thickness on the Bow Shock in Transonic Rotors. Review and Discussion. Review of Session I, Review of Session II, Discussion, Sessions I and II, Review of Session III, Discussion, Session III, Review of Session IV, Discussion, Session IV. Concluding Remarks. Concluding Remarks. Some Remarks On Present and Future Research Tasks in Fluid Mechanics. Workshop Participants. Index.

4.2.7 Combustion Measurements

a) Chairman: R. Goulard, The George Washington University, Washington, D.C.

b) Sponsored by: Office of Naval Research (Project SQUID), and the Air Force Office of Scientific Research.

c) Date: May 22-23, 1975.

d) Place: Purdue University, West Lafayette, Indiana.

e) References to Proceedings:

1. Report No. PU-RI-76. Proceedings of Workshop on Combustion Measurements.
   Edited by R.Goulard, Published for the ONR by School of Mechanical Engineering, Purdue University, West Lafayette, Indiana, 1975. Reference No. ADA 020 386.
2. Combustion Measurements
   Edited by R. Goulard, Hemisphere Publishing Corporation, Washington, D.C., 1976.

f) Contents of Proceedings

Preface. Thirty Years of Research. Needed Measurements in Combustor Technology. New Directions in Combustion Research. Combustion Models. Combustion Modeling (an APS summer study assessment). Elementary Combustion Reaction Kinetics Measurements at Realistic Temperatures. Some Conclusions Regarding Combustion Measurements Reached at the SAI/NSF (RANN) Workshop on the Numerical Simulation of Combustion. Combustor Design and Phenomenology. Phenomenology and Design of Jet Engine Combustors. Laser Velocimetry. Laser Velocimetry for Combustion Measurements in Jet Propulsion Systems. Laser Velocimeter Measurements of a Confined Turbulent Diffusion Flame Burner. Problems of Laser Velocimeter Application. Laser Anemometry in High Velocity, High Temperature Boundary Layers. Absorption-Emission and Resonance Techniques. Absorption-Emission Measurements in

Jet Engine Flows. Absorption-Emission Spectroscopy Applied to the Study of Pollutant Kinetics and Reaction Intermediates in High-Intensity Continuous Combustion. Boundary Layer Measurements of Temperature and Electron Number Density Profiles in a Combustion NHD Generator. Concentration Measurements by Fluorescence. Local Species Concentration Measurement by Resonance Scattering Technique. Discussion (session on absorption-emission and resonance techniques) Scattering Measurements. Raman Scattering Studies of Combustion. Application of Laser Diagnostics to Combustion. Gas Concentration and Temperature Measurements by Coherent Anti-Stokes Raman Scattering. Coherent Anti-Stokes Raman Spectroscopy (CARS) in Liquids and NRL's Program on Gases. Comparison of Density and Temperature Measurement Using Raman Scattering and Rayleigh Scattering. Laser Modulated Particulate Incandescence Noise Effects in Laser Raman Scattering Diagnostics. Raman Measurements of Specie Concentration and Temperature in an Aircraft Turbine Exhaust. Raman Scattering from Laminar and Turbulent Flame Gases. Interferometry. Interferometric Flame Temperature Measurements. Progress on Improved Flow Visualization by Resonance Refractivity. Holography and Holographic Interferometry. Measurement of Asymmetric Temperature Fields by Holographic Interferometry. Experimental Capabilities of Holographic Interferometry in Combustion. Holographic Two-Wavelengths Interferometry for Measurement of Combined Heat and Mass Transfer. Probe Methods and Special Techniques. Probe Measurements in Laminar Flows. Probe Measurements in Laminar Combustion Systems. New Results of Studies of Combustion Flows Obtained at the ONERA. In Situ Optical Versus Probe Sampling Measurement of No Concentration in Jet Engine Exhaust. Probe Measurements in Turbulent Flows. Probe Measurements in Turbulent Combustion. Modeling of Combustion Phenomena with Large Rates of Heat Release. Turbulent Mixing. Particulate

Measurements in Combustion. Particulate Measurement in the Exhaust of Gas Turbine Engines. Optical Methods for In Situ Determination of Particle Size-Concentration-Velocity. Distributions in Combustion Flows. Laser Scattering from Moving, Polydisperse Particle Systems in Flames. Particulate Measurements in Combustion. Burning Spray Measurements. Droplet Effects in Combustion. Discussion (session on particulates). Forum. Introduction. Velocity. Concentrations. Temperature. The Spray Region and the Combustor Environment. Turbulence. Review and Suggested Experiments. Introduction. Measurement Techniques. Combustion Measurements. References. Conclusions and Recommendations. Workshop Participants. Index.

4.2.8 Unsteady Flows in Jet Engines

a) Chairman: F.O. Carta, Purdue University, West Lafayette, Indiana.

b) Sponsored by: Office of Naval Research Program.

c) Date: July 11-12, 1974.

d) Place: United Aircraft Research Laboratories.

e) Reference to Proceedings:

1. Report No. UARL-3-PU: Proceedings of Workshop on Unsteady Flows in Jet Engines.
   Edited by F.O. Carta, Published for the ONR by School of Mechanical Engineering, Purdue University, West Lafayette, Indiana, 1974. Reference No. ADA 003 853.

f) Contents of Proceedings

Welcoming Comments. Foreword. Introduction. Compressor-Diffuser Interaction with Circumferential Flow. Aircraft. Discussion. The Response of an Axial Compressor to Unsteady Disturbances. Unsteady Fluid Dynamic Response of an Isolated Rotor with Distorted Inflow. Laboratories. Discussion. Short Talks. On-Rotor Studies of Rotating Stall. Polytechnic Institute and State University. Discussion. Unsteady Flows in an Annular Supersonic Blade Cascade. J. Fabri, ONERA. Discussion. Effect of Blade Row Geometry on Axial Flow Rotor. Unsteady Response to Inflow Distortion. Pennsylvania State University. Discussion. Dynamic Stall Detection and Design Aids for Distortion Tolerant Compressors Using Quasi-Steady Actuator Disc Analysis. Motoren- und Turbinen- Union. Discussion. Unsteady Response of Compressor Rotors to a 90° Circumferential. Pressure Distortion. Technology. Discussion. Short Talks. The Basis of a Field Method for the Calculation of Unsteady Flow in Cascades. Unsteady Supersonic Flow Around an Airfoil. The Unsteady Supersonic Flow Downstream of an Oscillating Airfoil. Unsteady Airloads on a Cascade of Staggered Blades in

Incompressible Flow. W.H. Heiser, Air Force Aero-Propulsion Laboratory, Chairman. Invited papers. Rotating Stall Research at Calspan. Some Comparisons of the Flow Characteristics of a Turbofan Compressor System with and without Inlet Pressure Distortion. Short talk. Experimentally Observed Three-Dimensional Effects of Circumferential Distortion: Invited papers. Air Force Overview. A Cascade in Unsteady Flow - A Progress Report. Prediction of Maximum Time-Variant Inlet Distortion Levels. Linearized Theory of Nonstationary Cascades at Part-Stalled Conditions. Oscillating Boundary Layers with Large Amplitude: Short Talks. Techniques for the Experimental Study of Unsteady Flow Effects in Turbomachines. The Need for and Future Direction of Research in Determining a Circumferential Inlet Pressure Distortion Index for Axial Flow Compressors. Influence of Loading on the Unsteady Aerodynamics of Turbomachine Blades. Rotating Stall in a 5-Stage Transonic Compressor. Panel Discussion. List of Participants.

4.2.9 Turbulent Mixing in Non-Reactive and Reactive Flows

a) Chairman: S.N.B. Murthy, Purdue University, West Lafayette, Indiana.

b) Sponsored by: Office of Naval Research (Project SQUID), and the Air Force Office of Scientific Research.

c) Date: May 20-21, 1974.

d) Place: Purdue University, West Lafayette, Indiana.

e) References to Proceedings:

1. Report No. PU-R2-74: Proceedings of Workshop on Turbulent Mixing in Non-Reactive and Reactive Flows.
   Edited by S.N.B. Murthy, Published for the ONR by School of Mechanical Engineering, Purdue University, West Lafayette, Indiana, 1974. Reference No. ADA 006 322.

2. Turbulent Mixing in Non-Reactive and Reactive Flows
   Edited by S.N.B. Murthy, Plenum Press, New York, 1974.

f) Contents of Proceedings

Introduction. Turbulent Mixing in Non-Reactive and Reactive Flows: A Review. Turbulent Modelling: Solved and Unsolved Problems. On the Modelling of the Scalar-Correlations Necessary to Construct a Second-Order Closure Description of Turbulent Flow. Computational Studies of Turbulent Flows with Chemical Reaction. Recent Advances in Theoretical Descriptions of Turbulent Diffusion Flames. Turbulent Mixing in Systems with Simple Reactions. Turbulent Mixing Studies in a Chemical Reactor. Comments on Unmixedness. Velocity and Pressure Characterization of Coaxial Jets. A Probability Distribution Function for Turbulent Flows. Mixing in "Complex" Turbulent Flows. Coherent Structures in Turbulence. Large Scale Motion in Turbulent Boundary Layers. Some Remarks on Synthetic Turbulent Shear Flows. Progress and Problems in Understanding Turbulent Shear Flows. Ensemble-Averaged Large Scale Structure in the Turbulent Mixing Layer. Some Observations on the Mechanism of Entrainment. Supersonic Free Turbulent Mixing Layers. Studies Related to Turbulent Flows Involving Fast

Chemical Reactions. Diffusion-Limited First and Second Order Chemical Reactions in a Turbulent Shear Layer. On Turbulence Structure and Mixing Mechanism in Free Turbulent Shear Flows. Conditional (Point-Averaged) Temperature and Velocities in a Heated Turbulent Plane. Diffusion from a Periodically Heated Line-Source Segment and its Application to Measurements in Turbulent Flows. General Discussion.

4.2.10 Laser Raman Gas Diagnostics

a) Chairmen: Marshall Lapp and C.M. Penney, General Electric Company, Schenectady, New York.

b) Sponsored by: Office of Naval Research (Project SQUID), the Air Force Aero Propulsion Laboratory, and the General Electric Co.

c) Date: May 10-11, 1973.

d) Place: Schenectady, New York.

e) References to Proceedings:

1. Laser Raman Gas Diagnostics, Edited by Marshall Lapp and C.M. Penney. Reference No. Ad 782 652.
2. Laser Raman Gas Diagnostics
   Edited by Marshall Lapp and C.M. Penney, Plenum Press, New York, 1973.

f) Contents of Proceedings

Foreword. Introduction. Session I - Introduction; Density Measurements. Laser Raman Scattering Applications. Analysis of Raman Contours in Vibration-Rotation Spectra. Measurement of Aircraft Turbine Engine Exhaust Emissions. The Use of a Fabry-Perot Interferometer for Studying Rotational Raman Spectra of Gases. Gas Concentration Measurement by Coherent Raman Anti-Stokes Scattering. Session II - Temperature Measurements; Chemistry. Flame Temperatures from Vibrational Raman Scattering. Measurement of Vibrational and Rotational-Translational Temperatures Independently from Pure Ratational Raman Spectra. Raman Scattering and Fluorescence Studies of Flames. Measurement of Rotational Temperatures by Raman Spectroscopy: Application of Raman Spectroscopy to the Acquisition of Thermodynamic Values in a Chemical System. Transient Flow Field Temperature Profile Measurement Using Rotational Raman Spectroscopy. Low Temperature Measurements by Rotational Raman Scattering. Session III - Resonance Effects:

Remote Probes; Experimental Advances. Light-Scattering and Fluorescence in the Approach to Resonance- Stronger Probing Processes. Observation of S-Band Heads in the Resonance Raman Spectrum of Iodine Vapor. Remote Raman Scattering Probes. Rapid and Ultra Rapid Raman Spectroscopy. Electronic Signal Processing for Raman Scattering Measurements. Session IV - Technology Applications. Introductory Remarks for Session on Technological Applications of Raman Scattering, with Emphasis on Fluid Mechanics and Combustion. Laser Raman Scattering - A Technique for Arc-Tunnel Flow Calibration. Results of Recent Applications of Raman Scattering to Research Problems at NASA Langley Research Center. Raman Scattering Measurements of Mean Values and Fluctuations in Fluid Mechanics. Raman Gas Mixing Measurements and Ramanography. Raman Scattering with High Gain Multiple-Pass Cells. Preliminary Results of Raman Scattering Diagnostics of Expansion Flows. Study of Reactions Producing Virbrationally-Excited Nitrogen. Application of Raman Scattering to Gasdynamic Flows. Remote Raman Temperature Measurement with a Dye Laser. Raman Spectroscopy of Some Hydrocarbons and Freons in the Gas Phase. The Possible Application of Raman Scattering Measurements to Turbulent Mixing Layers. Fourier Transform Raman Spectroscopy. List of Attendees. Author Index. Subject Index.

4.2.11 Aeroelaxticity in Turbomachines

a) Chairman: S. Fleeter, Purdue University, West Lafayette, Indiana.

b) Sponsored by: Detroit Diesel Allison, Division General Motors Corporation.

c) Date: June 1-2, 1972.

d) Detroit Diesel Allison

e) References to Proceedings:

1. Aeroelasticity in Turbomachines, Edited by S. Fleeter. Reference No. AD 749 680.

f) Contents of Proceedings

Introduction. Acknowlegments. List of Participants. PART I - MAIN PRESENTATIONS, AEROELASTICITY IN TURBOMACHINES. Perspectives in Aeroelasticity. On the Unstalled, Subsonic, Sonic and Supersonic Aerodynamic Coefficients Necessary for Aeroelastic Calculation. Unsteady Cascade Flow--A Schlieren Study. Unsteady Forces Acting on Turbomachine Blades. Unsteady Cascade Aerodynamics Including Compressibility Effects. Torsinal Flutter of Unstalled Blades at High Subsonic Mach Numbers. Supersonic Unstalled Torsional Flutter. Unsteady Transonic and Supersonic Cascade Flows. Semi-Empirical Analysis of Stall Flutter. Flutter of Cylindrical Shells Exposed to a Swirl Type of Flow. Flutter of a Cylindrical Shell in a Swirling Flow. Determination of Turbine Blade Damage from Noise Spectrum Measurements. PART II - PANEL DISCUSSION, RESEARCH NEEDS. Questions and Answers.

4.2.12 Fluid Dynamics of Unsteady, Three-Dimensional Separated Flows

a) Chairmen: D.E. Abbott and J.C. WU, Purdue University, West Lafayette, Indiana.

b) Sponsored by: Office of Naval Research Program.

c) Date: June 10-11, 1971.

d) Place: The Georgia Institute of Technology.

e) References to Proceedings:

1. Fluid Dynamics of Unsteady, Three-Dimensional Separated Flows, Edited by F.J. Marshall. Reference No. AD 736 248.

f) Contents of Proceedings

Introduction. Acknowledgements. List of Participants. Part I - Main Presentations. Dynamic Flow in Engine Air Inlets for Subsonic Aircraft. Behavior of Diffusers with Distorted and Unsteady Inlet Conditions. Analysis of Non-Linear, Unsteady, Inviscid Flows Including Blade to Blade Interactions. An Analysis of the Unsteady Compressible Turbulent Boundary Layer. A Generalized Method for the Calculation of Three-Dimensional Turbulent Boundary Layers. General Analysis of Unsteady Boundary Layers, Laminar and Turbulent. An Analysis of Laminar Separation-Bubble Flow Using the Navier-Stokes Equation. Numerical Solution of Unsteady, Three-Dimensional Navier-Stokes Equations. Unsteady Boundary Layer Separation. Panel Discussion. Part II - 10 Minute Presentations. Dynamic Stall on a Helicopter Rotor Blade. Numerical Solutions of Unsteady Inviscid Flow Problems. Short Unseparated Diffuser. Numerical Calculation of the Three-Dimensional Turbulent Boundary Layer on a Sharp Cone at Incidence in a Supersonic Flow. Calculation of Turbulent Separation in Adverse Pressure Gradients. Numerical Solutions of the Compressible Boundary Layer Equations for Laminar, Transitional, and Turbulent Three-Dimensional Flows. Unsteady Velocity Field Near the Leading Edge of a Flat Plate. A

Theoretical Study of the Effect of Unsteady Pressure Gradient Reduction on Dynamic Stall Delay. Steady and Nonsteady Potential Flow Methods for Airfoils with Spoilers. Recompression of Turbulent Free Shear Layer and Base Pressure Problems. Unsteady Boundary Layer Separation over Oscillating Airfoils. Velocity Amplification in Forward Stagnation Flow. The Wave Type Vortex Generator. Numerical Solution of the Time Dependent Navier-Stokes Equations. The Case for Extended Boundary-Layer Equations. Laminar Supersonic Flow over a Small Rearward Facing Step. Experimental Investigation of Turbulent Transonic Separated Flows.

4.2.13 Research in the Gas Dynamics Of Jet Engines

a) Chairmen: R. Goulard and M. L'Ecuyer, Purdue University, Indiana.

b) Sponsored by: Office of Naval Research Program.

c) Date: December 4-5, 1969.

d) Place: Squid Workshop, Chicago, Illinois.

e) References to Proceedings:

1. Research in the Gas Dynamics of Jet Engines, Edited by R. Goulard and M. L'Ecuyer.

f) Contents of Proceedings

Introduction and Acknowledgments. List of Participants. Some Thoughts About Possible Directions of Future Research In Jet Engine Technology. Performance of Propulsion Systems. Some Objectives in Jet Engine Research. The NASA Ad-Hoc Committee on Fluid Mechanics Problems in Aircraft Gas Turbine Engines. Fluid Dynamic Analysis for Blade Design. The Dynamic Simulation of Turbine Engine Compressors. Some Current Areas of Interest in Air-Breathing Propulsion Research. Turbine Cooling. Turboblade Vibrations. Small Gas Turbine Engine Problems. Fluid Dynamic Problems of Exhaust Systems. Areas of Needed Research.

4.3 Colloquia

4.3.1. Gas Turbine Combustor Modeling

a) Chairman: S.N.B. Murthy, School of Mechanical Engineering, Purdue University, West Lafayette, Indiana 47907.

b) Sponsorship: Air Force Office of Scientific Research and Office of Naval Research (Power Program).

c) Date: September 5 and 6, 1979.

d) Place: Purdue University, West Lafayette, Indiana.

e) Reference to Proceedings:

(1) Report No. PU-R1-79: Summary Report DOD Colloquium on Gas Turbine Combustor Modeling. September 1979. Published for ONR by School of Mechanical Engineering, Purdue University, West Lafayette, Indiana 47907. November 1979.

f) Contents: Introduction. Discussion of Objectives. Outline of the Report. Status of Modeling. Current Models. General Discussion. Specific Models. Recommendations. Applied Research Needs. Fundamental Research Needs in Advanced Detailed Modeling. Numerical-Computation. Model Validation. Role of Modeling.

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4.3.2. Flow Separation

a) Chairman: Roger L. Simpson, Southern Methodist University, Dallas, Texas 75272.

b) Sponsorship: Office of Naval Research (Power Program)

c) Date: January 18 - 19, 1979.

d) Place: Southern Methodist University, Dallas, Texas.

e) Reference to Proceedings:
Report No. SMU-3-PU: Summary Report on Colloquium on Flow Separation (January 1979).
Published for ONR by School of Mechanical Engineering.
Purdue University, West Lafayette, Indiana 47907.
August 1979.

f) Contents: Preface. Introduction. Terminology. Flow [illegible]. Flow Modeling. Measurements and Techniques. [illegible]. Control of Separated Flow. Concluding Remarks. References. Appendix I.

4.3.3. Raman Techniques for Measurements in Reactive Gaseous Environments

a) Chairman: S.N.B. Murthy, School of Mechanical Engineering. Purdue University, West Lafayette, Indiana 47907.

b) Sponsorship: Office of Naval Research (Power Program).

c) Date: January 12 - 13, 1978.

d) Place: Sandia Laboratories, Livermore, California.

e) Reference to Proceedings: A summary report on the Colloquium submitted by S.N.B. Murthy.

5. SPECIAL SERVICES

5.1. International Colloquium on Gas Dynamics of Explosions and Reactive Systems

5.1.1. Fourth International Colloquium, La Jolla, California

Proposal from Dr. S.S. Penner, University of California - San Diego, La Jolla, for funding of publication of proceedings was funded through Project SQUID.

Proceedings appeared in Acta Astronautica, Vol. 1.

5.1.2. Fifth International Colloquium, Stockholm, Sweden

Proposal from Dr. A. K. Oppenheim, University of California - Berkeley, Lawrence Livermore Laboratory, for funding of publication of proceedings was funded through Project SQUID.

Proceedings appeared in Acta Astronautica, Vols. 3 and 4.

5.1.3. Sixth International Colloquium, Gottinghen, Germany

Proposal from Dr. A.K. Oppenheim, University of California - Berkeley, Lawrence Livermore Laboratory, for funding of publication of proceedings was funded through Project SQUID.

Proceedings appeared in Acta Astronautica, Vols. 5 and 6.

5.2. International Workshop on Laser Velocimetry

Proposals received from Purdue University, West Lafayette, Indiana, for the support of the following Workshops were funded by the ONR through Project SQUID.

1) First International Workshop on Laser Velocimetry, held at Purdue University, March 9 - 10, 1972.

2) Second International Workshop on Laser Velocimetry, held at Purdue University, March 27 - 29, 1974.

In both cases, Dr. W.H. Stevenson and Dr. H.D. Thompson were the persons who requested funding, as Co-Chairmen of the Workshop and ediotors of Proceedings of Workshops.

Proceedings of the Workshops have been published as follows.

1) The Use of the Laser Doppler Velocimeter for Flow Measurements, Proceedings of a Workshop Co-sponsored by Project SQUID (ONR) and the U.S. Army Missile Command, March 9-10, 1972. W.H. Stevenson and H.D. Thompson. Reference No.: AD-753243.

2) Proceedings of the Second International Workshop on Laser Velocimetry, vols. I and II, March 27-29, 1974. W.H. Stevenson and H.D. Thompson. Published by Purdue University, West Lafayette, Indiana. Reference No.:

It may be noted that the Third International Workshop on Laser Velocimetry and Particle Sizing was held at Purdue University, July 11-13, 1978 and co-sponsored by the ONR Power Program, although not through Project SQUID. The proceedings of that Workshop is available as follows.

Laser Velocimetry and Particle Sizing, edited by Doyle Thompson and W.H. Stevenson, Hemisphere Publishing Corporation, Washington: 1979.

5.3. Consulting Services of Dr. Gordon and Dr. Tardy on Special Projects of ONR (Power Project)

Funding for the Consulting Services was provided by the ONR through Project SQUID.

Certification was received from the Office of Naval Research that consulting services had been performed satisfactorily along with submission of required report to the ONR.

6. DISCUSSION

6.1. Thrust Areas

It can be observed from Section 2 that the thrust areas in the period October, 1967 through December, 1979, have changed as follows.

1) 1967 - 1969
   a) Fluid mechanics and MHD
   b) Atomic and molecular collisons
   c) Chemi-ionization and ion-molecule reactions
   d) Combustion and chemical rate processes

2) 1970 - 1972
   Same as the period 1967 - 1969 except that research in the area of MHD was not funded directly.

3) 1972 - 1973
   a) Fluid mechanics
   b) Combustion and molecular processes
   c) Measurement techniques

4) 1974 - 1979
   a) Aerodynamics and turbomachinery
   b) Turbulence
   c) Combustion and molecular processes/chemical kinetics
   d) Measurements

Subjects such as MHD-applications, chemi-ionization, ion-molecule reactions and properties of gases have become de-emphasized since 1972.

Fluid mechanics has always included some aspects of turbulence and measurement techniques, but since 1974, turbulence has been identified

as a distinct thrust area, especially chemically-reactive turbulent flows.

Measurement techniques, their development and application, have been identified as a thrust area since 1972 and has generally concentrated on optical/non-intrusive techniques for diagnosis and measurement.

Various aspects of the fluid mechanics and chemical kinetics of combustion have always been recognized as a thrust area, with emphasis recently on advanced and alternative fuels.

6.2 Possible Thrust Areas

The broad thrust areas of aerodynamics and turbomachinery, combustion and molecular processes, and measurements appear to be useful in the next five to seven year period.

Investigations in turbulent combustion *per se* may need further discussion.

Under aerodynamics, additional emphasis seems useful in engine-airframe integration related topics. In general, these problems involve "complex flows" or "complex interactions of flows".

In the area of fluid mechanics, one may particularly note the needs in these areas:

a) rotational internal flows,
b) fine passage flows,
c) multi-phase flows,
d) transitory flows, and
e) aero-elastic interactions.

In each of the foregoing, measurements will play a significant role.

Numerical-computer experiments indicate a further direction for research.

Regarding development of diagnostic and measurement techniques, some caution is required in regulating sporadic and unproductive research. Understanding of phenomena, generation of data especially from the point of view of modeling processes and uncovering easily-applicable and reliable techniques should continue to be the goals of work in this area.

6.3. Workshops and Colloquia

Project SQUID has organized a series of workshops and colloquia. They have proved extremely effective in the evolution of fruitful areas of research, in generating interest in the community in various technical areas and, most significant of all, in focussing research on recognizable goals.

This important activity of Project SQUID should be continued.

The ONR role in the workshops and colloquia, other than as the sponsoring agency, has consisted in the past in active participation through providing guidance and clarifications. In general, a workshop or colloquium has been conducted by a chairman, selected by the ONR from the university-research community, so that a free exchange of views is assured.

The publication of proceedings of workshops and colloquia, so that it is available to the public, has been much appreciated.

6.4 Project Organization

6.4.1. Project SQUID, devoted to basic research needs in propulsion of

long-range relevance to the Navy, has developed over the years a strong university involvement in (a) identifying research areas, (b) encouraging development of proposals, (c) reviewing proposals, on-going contractual research and technical reports and (d) providing assistance to the ONR in the development of a well-synthesized program by conducting workshops and colloquia.

Such an involvement is extremely useful, and in many respects necessary, in the organization of basic research in an advanced technology area such as propulsion which is inter-disciplinary in various engineering and applied sciences.

6.4.2 Project SQUID research may prove even more effective, particularly in its translation into "exploratory development", if "Centers of Project SQUID" are organized in addition to "Individual Research Projects".

A Center of Project SQUID can be located at an Institution where Propulsion has become established as a "thrust-area" with adequate personnel and facilities. A Center of Project SQUID should conduct research in a selected broad area with the participation of a number of investigators. Funding may be assured over a pre-determined period of years, subject to annual review. A Center for Project SQUID should be encouraged to work closely with an industrial organization wherever possible.

In the broad area of jet propulsion related to aircraft and missiles, the following are of primary interest: (a) variable cycle and geometry engines; (b) modular construction of engines; (c) engine-airframe/vehicle integration; (d) fuels and combustion; and (e) diagnostics and measurement. Whether one is considering rockets, air-breathing missilies, V/STOL systems, supersonic military aircraft or hypersonic air-breathing engines, the afore-mentioned five broad areas will prove of basic significance. In each of those areas, one can again recognize certain smaller subject areas

for concentrated effort, either from considerations of priority or from considerations of the length of time required for useful results to accrue. Such a subject area then will become the research subject-area for a Center for Project SQUID.

Some examples of broad areas of basic research related to Navy interest in propulsion are as follows: (1) Alternative fuels, physical, chemical and combustion characteristics, (2) Measurements in hostile engine environments, (3) Heat and mass transport processes in combustors and turbines, (4) Advanced turbo-machinery aero/mechanical design, (5) Small scale fluid dynamics, (6) Modeling of complex and interacting flows.

6.4.3. Project SQUID has been a unique example of organizing basic research related to an area of advanced technology, where industry itself is endeavoring continuously through internal development efforts to meet international competition both in basic and operational costs of the product, namely jet propulsion engines. The particular organization of Project SQUID, under which work reported here has been performed, has been extraordinarily successful as is evidenced by this report. The possibility of publication of research activities under the project in a single report is in itself a feature of the project.

Project SQUID research has had continuous impact on engine technology, not in terms of specific improvement in one or other component or aspect of performance, but in two extremely important respects: (a) demonstrating the importance and benefit of obtaining basic understanding of various phenomena in universalizing the results of ad hoc investigations and (b) creating a climate for utilizing results of research as an important contributor to life cycle improvement and total cost reduction.

Such objectives have been met through several features of the organization itself:

(1) Designated funding that has not been changed due to ordinary exigencies of circumstances.
(2) Detailed and open review of proposals and on-going contracts.

(3) Reporting of results of research through designated technical and semi-annual reports.

(4) Sponsoring Workshops and Colloquia from time to time for synthesizing and assessing research activity in various subject-areas.

(5) Association of an active researcher in the area with the technical evaluation of research projects on a continuous basis and of selected consultants as and when desirable.

The third of the above has been appreciated very greatly by the investigators from the point of view of scientific/technical developments. The outside "Technical Director" has, without any managerial or executive authority, performed a complementary role to that of the ONR Director of the Project in the evolution of Project activities. It has been an invariably successful, and in several respects necessary, addition to the management of this type of research activity.

Planning of basic research is in some respects a contradiction in terms. On the other hand, sustained support for basic research requires recognition of schools of approach to various problems and continuous review of research directions. Project SQUID operation - its assessment, review and reporting processes - has been uniquely successful in providing both continuity and critical evaluation in each of the subjects it has concetrated on at any given time.

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